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RESIDUES IN FISH, WILDLIFE, AND ESTUARIES

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Mirex Residues in Selected Estuaries of South Carolina—June 1972 [1]

P. W. Borthwick,[2] G. H. Cook,[2] and J. M. Patrick, Jr.[2]

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ABSTRACT

Estuarine sediments, crabs, shrimps, and fishes were collected in June 1972 at eleven stations two years after aerial applications of mirex bait for control of fire ants in coastal areas near Charleston, S.C. These stations had previously been monitored (October 1969 to June 1971) when levels of mirex in animal samples were: crabs, 0-0.60 ppm; shrimps, 0-1.3 ppm; and fishes, 0-0.82 ppm.

The recent study showed that mirex was present in three species of fishes (white catfish, 0.021 ppm; bluegill, 0.047 ppm; carp, 0.12 ppm) and blue crabs (0.026 ppm) at two freshwater stations. However, mirex was not detected in 36 animal samples, most of which were taken from nine saline stations in the estuaries after a period of restricted use of the pesticide. Analysis of bottom sediment samples at all stations detected no mirex. The lower limit of detection for mirex was 0.01 ppm.

Introduction

In June 1972 samples of estuarine sediments, crabs, shrimps, and fishes were collected at 11 stations near Charleston, S.C., where mirex fire ant bait had been applied aerially to coastal areas from October 1969 to December 1970. The United States Department of Agriculture supervised two applications of mirex, by fixed-wing aircraft, to several hundred thousand acres in the Charleston area. Treatments were terminated approximately 24 months before the June 1972 collections. However, 18 months lapsed since special applications were made by helicopter to 1200 acres at Toogoodoo Creek: Stations A, B, C, and D; and by hand seeder around a one-acre pond at Riverland Terrace: Station 1 (Fig. 1).

Since 1970 less extensive applications have been made for control of nuisance populations of fire ants. During the 1971-72 cooperative Federal State Control Program, mirex bait was applied aerially in South Carolina and seven other Southeastern states at property owners' requests.

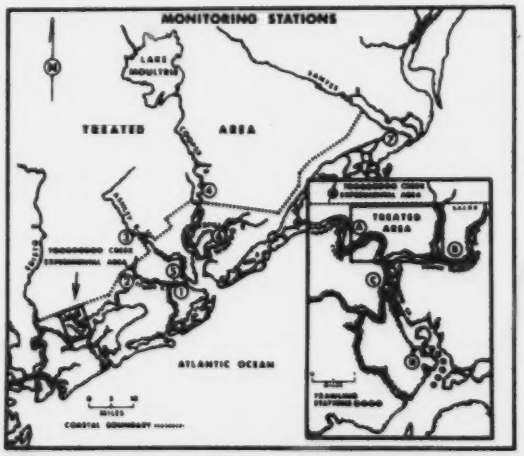

FIGURE 1—*Map of study area showing location of mirex sampling sites, South Carolina—June 1972*

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The use of mirex decreased when the U.S. Environmental Protection Agency (U.S. EPA) issued orders (*1*, *2*) to cancel the registration of products containing mirex, pending relabeling. The orders required that no mirex be applied aerially near estuaries and other aquatic areas, wildlife refuges, or heavily forested areas. The present study was implemented to determine how much mirex remained in the estuarine fishes and crustaceans following a period of restricted use of the pesticide.

The stations (Fig. 1) and analytical techniques were identical to those used in a more comprehensive study of the area (*3*). Samples were collected and analyzed by the United States Environmental Protection Agency, Gulf Breeze Environmental Research Laboratory, Gulf Breeze, Florida.

Results and Discussion

In June 1972, 24 months after large-scale aerial treatment of inland areas, mirex residues greater than 0.01 ppm were found in only 4 of 40 animal samples (Table 1). All four samples were collected at the two freshwater stations located on the Ashley and Cooper Rivers (Stations 3 and 4, Fig. 1) which drain watersheds within the treated area. Three species of freshwater fishes and blue crabs contained the following amounts of mirex (ppm):

white catfish	0.021
bluegill	0.047
carp	0.12
blue crabs	0.026

Except for the bluegill, these animals are omnivorous bottom-dwellers. Blue crabs are euryhaline; they occasionally enter brackish and fresh waters of estuaries.

Mirex was not detected (Table 1) in the remaining 36 animal samples, most of which were taken at 9 stations located on tidal creeks in salt marsh areas that support populations of finfish and crustaceans. Many of these animals are transient and spend only a portion of their lives in the estuary. No mirex was detected in bottom sediments sampled at each location.

The lower limit of detection for mirex with the method employed (*3*) was 0.01 ppm.

Between October 1969 and June 1971 mirex residues in economically important members of the estuarine food chain varied as follows: crabs, 0-0.60 ppm; shrimps, 0-1.3 ppm; and fishes, 0-0.82 ppm. Levels of mirex in these species diminished to less than 0.01 ppm over a period of 18 to 24 months after the last aerial broadcast treatments to coastal South Carolina.

LITERATURE CITED

(*1*) *Ruckelshaus, W. D. 1972.* Products containing the insecticide mirex; determination and order of the Administrator. Fed. Regist. 37(106): 10987-10988.

(*2*) *Ruckelshaus, W. D. 1972.* Products containing the insecticide mirex; determination and order. Fed. Regist. 37(130): 13299-13300.

(*3*) *Borthwick, P. W., T. W. Duke, A. J. Wilson, J. I. Lowe, J. M. Patrick, Jr., and J. C. Oberheu. 1972.* Accumulation and movement of mirex in selected estuaries of South Carolina, 1969-1971. Pestic. Monit. J. 7(1): 6-26.

TABLE 1.—*Whole body mirex residues, ppm, in estuarine animals, and sediments of South Carolina—June 1972*

Station Location	Toogoodoo Creek				Riverland Terrace Pond	Stono River	Upper [2] Ashley River	Cooper [2] River	Lower Ashley River	Wando River	South Santee River
Species / Station Identification:	A	B	C	D	1	2	3	4	5	6	7
CRABS											
Callinectes sapidus (blue crab)	—[1]	—	—	—	—	—	—	0.026	—	—	—
Uca pugilator (sand fiddler)			—								
SHRIMPS											
Penaeus aztecus (brown shrimp)	—	—	—	—	—	—		—	—	—	—
Palaemonetes pugio (grass shrimp)					—						
FISHES											
Leiostomus xanthurus (spot)	—		—	—	—	—	—	—	—	—	
Bairdiella chrysura (silver perch)		—						—			—
Ictalurus catus (white catfish)							0.021				
Cyprinus carpio (carp)								0.12			
Lepomis macrochirus (bluegill)							0.047				
MOLLUSKS											
Crassostrea virginica (oyster)			—								
Mercenaria mercenaria (hard clam)								—			
SEDIMENT	—	—	—	—	—	—	—	—	—	—	—

[1] — indicates <0.01 ppm mirex.
[2] Freshwater stations.

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BRIEF

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Mercury Levels in Soils of the Eastern United States

G. B. Wiersma[1] and H. Tai[2]

ABSTRACT

Cropland and noncropland soils were sampled to determine levels of elemental mercury present in the upper three inches of soil. Results showed no difference in mercury levels between cropland and noncropland soils. Levels detected compared closely to levels found in similar studies. Actual mean levels of mercury residues in soils of the eastern United States ranged from 0.05 to 0.10 ppm.

Introduction

This study is an effort to determine baseline levels of elemental mercury in cropland and noncropland soils in the eastern United States. These baselines, in turn, will be used for comparison with results from continuing soil monitoring efforts for pesticides containing mercury.

Several estimates have been made of baseline levels of mercury in soils, both in the United States and abroad. Warren and Delavault (*1*) reported very high concentrations of mercury in certain British soils ranging as high as 15 ppm. They estimated, however, that the levels of mercury in most British agricultural soils would probably range between 0.01 and 0.06 ppm. Anderson (*2*) analyzed soils in Sweden and found that ranges for mercury in these soils varied from 0.02 to 0.92 ppm with an average of 0.07 ppm. Sand et al. (*3*) reported mercury residues in wheat-growing areas of the north-central United States.

Pierce et al., (*4*) reported mercury concentrations in soil from four areas in the western United States. The 50 percentile points for these four sets of data ranged from 0.071 ppm to 0.200 ppm. Shacklette et al. (*5*) collected 912 soil samples along widely scattered road systems in the continental United States. Sample sites were approximately 50 miles apart.

Sampling was conducted to the depth of 8 inches. The geometric means for mercury concentration in these soil samples for the entire United States was 0.071 ppm. The arthmetic mean was 0.112 ppm. The geometric mean for the western United States, 492 samples from west of the 97th meridian, was 0.055 ppm; the arithmetic mean was 0.083 ppm. The eastern United States, 420 samples, had a geometric mean of 0.096 ppm and an arithmetic mean of 0.147 ppm.

Material and Methods

Samples were collected as a subset of the National Soils Monitoring Program as described by Wiersma et al. (*6*). Sites were allocated according to the relative amounts of cropland and noncropland acreages in each State. Sites were chosen at random within the two categories. States sampled and the number of sites in each state are listed in Table 1.

At each sampling point a 10-acre site was sampled. Fifty soil cores, 2 inches in diameter by 3 inches deep, were collected and composited with the use of a 5-by-10 grid. A 2-quart subsample was then taken and sent to the laboratory for analysis. The cropland samples were collected in the fall of 1968, along with noncropland samples from Georgia, Maine, Maryland, Virginia, and West Virginia. All other noncropland samples were collected in the spring of 1971.

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TABLE 1.—*Soil samples collected to determine mercury residues in surface cropland and noncropland areas of eastern United States*

State	Number of samples collected	
	Cropland	Noncropland
Alabama	6	6
Arkansas	13	5
Connecticut	1	1
Delaware	1	No samples tested
Florida	5	7
Georgia	8	8
Illinois	41	3
Indiana	22	1
Kentcuky	8	4
Louisiana	8	5
Maine	2	2
Maryland	3	1
Massachusetts	1	1
Michigan	16	*
Mississippi	9	5
Missouri	23	7
New Hampshire	1	1
New Jersey	*	1
New York	11	5
North Carolina	8	6
Ohio	18	3
Oklahoma	19	7
Pennsylvania	11	5
South Carolina	5	3
Tennessee	8	5
Vermont	1	1
Virginia	7	4
West Virginia	3	2
Wisconsin	16	5
TOTAL	275	104

* No analyses available

Analytical Procedures

The analyses were done by a commercial laboratory in West Chester, Pennsylvania, under contract with the U.S. Environmental Protection Agency. The flameless atomic absorption spectrophotometry was applied for the determination of mercury.

Each soil sample, weighed exactly to 1.000 g, was dispersed in nitric acid solution (5 ml concd HNO_3 in 100 ml water). Digestion at 90°C, for approximately 2 hours, took place in the presence of excess potssium permanganate (portions of 1 ml 5% $KMnO_4$ solution were added until purple color persisted) and 2 ml of 5% potassium persulfate solution. After digestion, the mixture was cooled to room temperature and filtered. The filtrate was made to a volume of 100 ml, and 2 ml of sodium chloride-hydroxylamine reagent (12 g each in 100 ml water) was added to reduce the excess permanganate. Stannous sulfate solution (25 g in 250 ml of 0.5N H_2SO_4), 5 ml, was added to reduce mercury ions to elemental mercury, which was swept by an air stream through the absorption cell of the atomic absorption spectrophotometer. The absorptions were measured by peak height, and compared with a calibration curve.

A Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer with Automatic Null Recorder Readout was used for the measurements. The essential instrument conditions were:

Lamp:	Mercury Hollow Cathode Lamp (Westinghouse WL-22847)
Lamp current:	10 mA
Wave length:	253.7 nm
Slit setting:	3
Scale:	× 1
Noise suppression:	2

Precision study, using samples not reported in this paper, indicated a standard deviation of ± 0.16 at a level of 0.35 μg/liter, with recovery average of 87%. The present procedure gave a detection limit of 0.05 μg mercury (or 0.05 ppm per 1-g sample).

Results and Discussion

After testing the distribution form of our data, we found that the data for mercury levels were not normally distributed with both positive skewness and significant kurtosis present. We found, however, that a logarithmic transformation helped the data to approach the normal distribution and to have a symmetric distribution. Shacklette et al. used logarithms to transform their data. They felt that the geometric mean was the best estimate of the central tendency of the data. We have found in our work similar results; therefore, we present both the arithmetic and geometric means. Table 2 shows the geometric means, 95% confidence levels, arithmetic means, the percent of samples that had detectable residues, and the detection range of mercury levels in both cropland and noncropland soils.

TABLE 2.—*Summary of mercury residues detected in surface cropland and noncropland soils of the eastern United States*

	Arithmetic Mean, ppm	Geometric Mean and 95% Confidence Interval, ppm	Range, ppm	Percent of Samples with Detectable Residues
Cropland	0.08	0.063 (0.069-0.058)	<0.05 to 1.06	100.0
Noncropland	0.07	0.054 (0.064-0.046)	<0.05 to 0.40	100.0

Mercury was present in all the samples collected at either a trace level or above. The difference between cropland and noncropland soils were not significant. This was determined from the overlapping confidence intervals. Although these samples were collected at different times, one would not expect mercury levels to change significantly from year to year.

Shacklette et al. have stated (5), "Surficial materials analyzed in this study are ordinarily sampled at a depth of 8 inches. We believe that soils and other regoliths from this depth commonly show little or no effects of surficial contamination that may have occurred." The samples in this study were collected to include possible

contamination of surface soil by pesticides and other pollutants containing mercury. If there had been a significant amount of mercury contamination from manmade sources that had reached soils through airborne or other routes, one would expect our samples to have considerably higher residues than those collected specifically to avoid surface contamination. However, the mercury levels reported in this study are actually lower than those reported by Shacklette et al.

To summarize: in mercury levels of the eastern United States there is no statistical difference between cropland and noncropland soils. The levels detected in this study agree closely with levels detected in similar studies. Actual mean levels of mercury residues in the soils of the eastern United States ranged from 0.05 to 0.10 ppm.

LITERATURE CITED

(1) *Warren, H. V. and R. E. Delavault. 1969.* Mercury content of some British soils. Oikos 20: 537-539.

(2) *Anderson, A. 1967.* Mercury in Swedish soils. Oikos (Supplement 9): pp. 13-15.

(3) *Sand, P. F., G. B. Wiersma, H. Tai and L. J. Stevens. 1971.* Preliminary study of mercury residues in soils where mercury seed treatments have been used. Pestic. Monit. J. 5(1): 32-33.

(4) *Pierce, A. P., J. M. Botbol, and R. E. Learned. 1970.* Mercury in the environment. Geological Survey Professional Paper 713. U.S. Department of the Interior, pp. 14-16.

(5) *Shacklette, H. T., J. G. Boerngen and R. L. Turner. 1971.* Mercury in the environment—surficial materials of the conterminous United States. Geological Survey Circular 644. U.S. Department of the Interior. 5 pp.

(6) *Wiersma, G. B., P. F. Sand, and E. L. Cox. 1971.* A sampling design to determine pesticide residue levels in soils of the conterminous United States. Pestic. Monit. J. 5(1): 63-66.

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Persistence of Parathion in Soil

by H. R. Wolfe, D. C. Staiff, J. F. Armstrong, and S. W. Comer

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Concern about persistence of synthetic pesticides in soil and the environment in general has been greater where chlorinated hydrocarbon compounds have been involved than where organophosphorus pesticides have been used. This is understandable, inasmuch as organophosphorus compounds generally degrade more rapidly in the environment. Most of the research concerning degradation or disappearance of organophosphorus compounds from soil has involved relatively low initial levels of pesticide resulting from conventional applications of the compounds for insect control. At these levels the degradation of organophosphorus compounds has generally been much more rapid than with chlorinated hydrocarbon compounds (1,2). Recently Stewart et al. (3) found traces of parathion in soil 16 years after the last application. The finding at this laboratory (4) that spillage of emulsifiable concentrate parathion and azinphosmethyl on soil at spray machine fill sites, air application flight strips, and other locations may be a hazard to children because of the presence of persistently high concentrations of the pesticides, has prompted our further investigation into the problem of persistence of organophosphorus compounds in soil. The purpose of the present study was to determine the disappearance of parathion residues in soil following topical applications of the compound. The results are intended to have application to problems related to waste pesticide disposal, of leaching, and of degradation or disappearance of parathion in the environment, as well as to the problem of hazard to children who may come in contact with contaminated spillage areas.

Materials and Methods

The experiment involved treatments of field soil plots using three liquid parathion concentrations and two different formulations. Treatments were: (a) undiluted commercial grade 45.6% liquid emulsifiable concentrate, (b) conventional dilute spray for orchard use prepared from water-wettable powder and containing 0.03% parathion (referred to as 1X concentration), (c) a dilute spray similar to (b) except prepared from emulsifiable concentrate, (d) a spray mixture of the type commonly used for semi-concentrate spray applications prepared from water-wettable powder and containing 0.24% parathion (8X--eight times the normal 1X

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concentration), and (e) a spray mixture similar to (d) except prepared from emulsifiable concentrate. The undiluted emulsifiable concentrate treatment was included in order to simulate spillage of concentrate pesticide and the more dilute concentrations were used because of the occasional practice of dumping various quantities of unused liquid spray formulation from spray machines onto the ground after finishing a particular spray operation. The undiluted emulsifiable concentrate and 8X treatments were replicated four times in each of three field plots. The 1X treatments were replicated four times in two field plots.

All experimental plots were subjected to the natural elements such as rainfall (average approximately 10 inches per year), sunlight (over 275 days during each year), and relatively high maximum temperatures (over 90°F for an average of 14 days each summer). The plots were covered with snow for approximately 2 months of each year. All three plots were sandy loam soil; however, plot 3 was on the verge of being classed as loamy sand. Plot 1 soil contained 11.2% clay, 34.2% silt, 54.6% sand, and 2.5% organic matter. The pH ranged from 4.4 to 5.4 with a mean of 4.7. This plot was subjected to sprinkler irrigation for a 24-hour period each 2 weeks during the summer season. The other two plots were not irrigated. Plot 2 soil contained 10.2% clay, 29.0% silt, 60.8% sand, and 3.4% organic matter. The pH ranged from 6.7 to 7.4 with a mean of 7.1. Plot 3 soil contained 6.0% clay, 26.0% silt, 67.3% sand, and 1.0% organic matter. The pH ranged from 6.6 to 7.8 with a mean of 7.3.

Metal frames 12-inches square were used to outline the individual soil test areas within each experimental plot. These were left in place for the duration of the experiment. The frames were pressed into the soil so that when 2 quarts of liquid parathion formulation were applied topically within the frame, a pool approximately 3/4-inch deep was formed before the material soaked into the soil. Samples of soil from two depths (0-1 in. and 1-3 in.) were taken 1 day following application and at intervals thereafter up to 5 years. At the 6th-year period two soil test areas were sacrificed and four replicate samples taken from each area at different depths in increments of 3 inches down to the 24-inch level.

Soil samples to the 3-inch level in all plots were taken by use of a cork borer tube which was cleaned after collection of each sample. Care was taken to minimize cross contamination between soil samples at different depths. However, it was difficult to avoid some cross contamination, due to limited surface area of test plots, especially after the 3rd year of sampling. It was felt that cross contamination of samples below the 3-inch depth was negligible because samples in this area were taken by

removal of entire layers of soil.

Parathion content of soil samples was determined in most cases by the method of Averell and Norris (5). In later years gas liquid chromatography was occasionally utilized as a check for accuracy and was used for analysis of deep soil samples where pesticide might be expected to be present in very low levels, if at all. This system was also used for analysis of paraoxon and other closely related alteration or breakdown products. Analysis for aminoparathion was by a modification of the Averell-Norris method and analysis for p-nitrophenol was by the method of Elliott et al. (6).

The effect of parathion on soil microorganisms was determined using number of colonies developed on nutrient yeast dextrose agar as an indicator. Soil innoculations at four different dilutions were made in 100 mm petri dishes containing the media. Because of the difficulty of accurately classifying the many different organisms found in soil they were divided into only two categories: filamentous and nonfilamentous.

Results and Discussion

As can be seen in Fig. 1, parathion persisted at relatively high levels for 5 years following gross topical contamination with the 45.6% emulsifiable concentrate formulation. The levels of pesticide in the soil, initially very high (30,000 to 95,000 ppm), were considerably lower by the end of the first year. By the second year the rate of disappearance was much less, with appreciable quantities remaining in both the top 1 inch and the 1- to 3-inch levels at the end of the 5th year. The lowest level found in a single sample at that time was 13,800 ppm (approximately 1.4%) parathion in the top 1 inch of soil. This level is higher than that involved in a near-fatal poisoning case where a child ingested soil from a contaminated area in a driveway near his home (7). In that incident the soil contained 8,634 ppm of parathion and was a result of spillage which had occurred at least 6 months prior to the incident.

There was no great difference in rate of disappearance of parathion among the three emulsifiable concentrate experimental plots. In individual plots more parathion was present in the top 1 inch of soil than in the 1- to 3-inch level for approximately 2 years; however, after that period the difference became much less. At 5 years some of the 3-inch depth samples contained more parathion than those from the 1-inch depth. At the 6-year period where soil was checked in increments of 3 inches down to the 24-inch level, very little parathion was found below the 9-inch level (see Table 1).

At the 4th-year period following application two emulsifiable concentrate plots were checked for presence of parathion alteration products in the top 3 inches of soil. Where parathion content of soil ranged from 16,662 to 26,746 ppm the amount of p-nitrophenol found ranged from 11.2 to 41.0 ppm. No aminoparathion, paraoxon or S-ethyl parathion could be detected. The inability to find aminoparathion was expected because of the great instability of the compound. Instrumentation available at the time the samples were analyzed was not adequate to properly identify and quantitate paraoxon and S-ethyl parathion. However, a recent recheck of the sample extracts by improved methods has indicated the presence of small amounts of paraoxon and S-ethyl parathion. Improved instrumental capability in recent years has allowed additional studies at this laboratory on parathion alteration products in soil which will be reported at a later date.

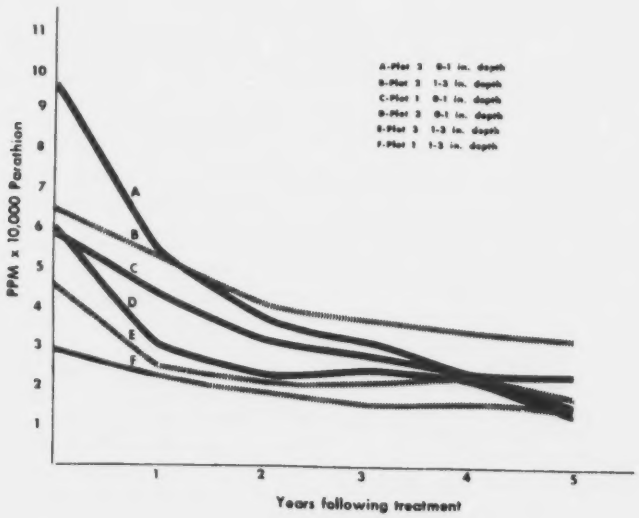

Figure 1. Disappearance of parathion from sandy loam soil, following gross topical contamination with emulsifiable concentrate formulation (45.6%), at two depths in three experimental plots. Each value average of 4 replicates.

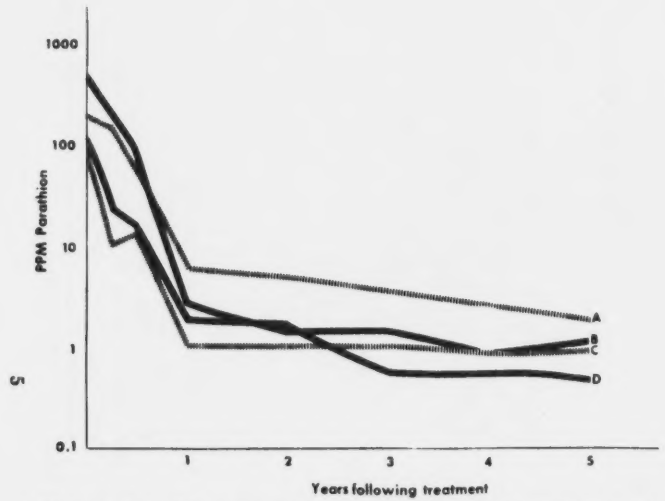

Figure 2. Disappearance of parathion from top 1 inch of sandy loam soil following topical applications of two concentrations using two formulations. A = 8X (0.24%) and C = 1X (0.03%) sprays using water-wettable powder formulation. B = 8X (0.24%) and D = 1X (0.03%) sprays using emulsifiable concentrate formulation. A and B average of 12 replicates and C and D average of 8 replicates.

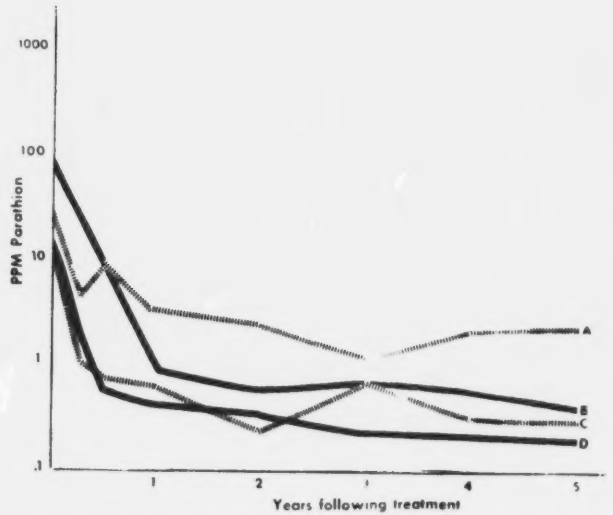

Figure 3. Disappearance of parathion from 1- to 3-inch depth of sandy loam soil following topical applications of two concentrations, using two formulations. A = 8X (0.24%) and C = 1X (0.03%) sprays using water-wettable powder formulation. B = 8X (0.24%) and D = 1X (0.03%) sprays using emulsifiable concentrate formulation. A and B average of 12 replicates and C and D average of 8 replicates.

TABLE 1

Parathion in Soil at Different Depths Six Years After Topical Application of Emulsifiable Concentrate Formulation (45.6%).

Depth (inches)	PPM Parathion*	
	Plot 1	Plot 2
0-1	14,500	15,370
1-3	14,900	9,330
3-6	9,900	9.65
6-9	149.4	9.48
9-12	0.004	0.097
12-15	0.048	0.008
15-18	0.004	0.017
18-21	0.011	el**
21-24	el**	el**

*Average of 4 replicates.

**Below lower limit of sensitivity of method (< 0.002 ppm)

Figures 2 and 3 show persistence of parathion at two depths in soil plots where the more dilute liquid spray concentrations were applied topically. There was very little difference in values obtained among these experimental plots; therefore, average values for replicates in the three plots were used in plotting the curves. As with the more concentrate applications discussed above, the levels of parathion in soil dropped off quite rapidly during the first year with a trend toward leveling off thereafter. Where the 1X (0.03%) concentration was applied, average levels after 5 years were from 0.6 to 1.2 ppm in the top 1 inch of soil and from 0.2 to 0.3 ppm in the 1- to 3-inch depth. Where the 8X (0.24%) concentration was applied, average levels after 5 years were 0.4 to 1.5 ppm in the top 1 inch of soil and from 1.2 to 3.6 ppm in the 1- to 3-inch level. It appears that slightly higher levels of pesticide remained in the soil after 5 years where water-wettable formulation was used than where the emulsifiable was used. Two sets of the experimental plots will be retained so that samples can be analyzed after much longer periods of time than 5 years. By using more sensitive methods, perhaps any differences at low levels can then be more clearly defined.

On finding relatively high levels of parathion in the top 3 inches of soil in the concentrate plots at the end of the 2-year period, we decided to determine if soil microorganisms were being appreciably affected. Soil isolations at four different dilutions were made on yeast-dextrose agar. Counts of the number of colonies that had developed in 6 days at 70°F were used as an indicator. As can be seen in Table 2, under the conditions of our experiment, fewer colonies were isolated from the concentrate parathion soil plot than from untreated control soil nearby. Also, when untreated control soil inoculum was placed in media containing 0.5% parathion the counts were considerably lower, and where the media contained 5.0% parathion the microorganism colony development was almost completely inhibited. Where the inoculum was from a plot treated with parathion 2 years earlier, and containing approximately 3.4% parathion, there was also similar reduction in the media containing 0.5% parathion, indicating that there had been no appreciable development of resistance to the pesticide by the organisms as indicated by the methods used in the test.

Table 3 shows results of inoculations of soil taken from another concentrate parathion plot at the 5th year following topical application with the pesticide. This is compared with untreated control soil inoculum taken nearby. In this experimental plot area the counts for the untreated control area were

TABLE 3

Effect of Parathion on Soil Microorganisms Expressed as Colony Numbers on Nutrient Yeast-Dextrose Agar Following Soil Isolations.

Sample	Culture Dilution in H_2O	Number of Colonies Developed in 6 Days at 70°F[a]	
		Nonfilamentous	Filamentous
1[b]	1-1000	2500.0	1000.0
	1-10,000	817.3	477.0
	1-100,000	181.0	100.3
	1-1,000,000	57.0	24.3
2[c]	1-1000	89.0	18.6
	1-10,000	21.3	4.6
	1-100,000	5.6	0.6
	1-1,000,000	2.6	1.0

[a] Each value is average of counts observed on three 100 mm petri dishes. Sampled from top 1 inch of soil.
[b] Untreated control soil near treated plots.
[c] Soil 5 years after topical application with 45.5% emulsifiable concentrate. Approximately 2.9% parathion at time of sampling.

TABLE 2

Effect of Parathion on Soil Microorganisms Expressed as Colony Numbers on Nutrient Yeast-Dextrose Agar Containing Different Levels of Parathion as an Indicator.

Media	Culture Dilution in H_2O	Number of Colonies Developed in 6 Days at 70°F[a]			
		Soil from Control Plot Containing no Parathion		Soil from Test Plot Containing approx. 3.4% Parathion[b]	
		Nonfilamentous	Filamentous	Nonfilamentous	Filamentous
A:					
Contained	1-1000	< 200.0	10.0	106.0	0.0
no	1-10,000	83.0	6.7	26.7	0.0
Parathion	1-100,000	61.7	9.0	3.7	0.0
	1-1,000,000	24.7	4.7	4.3	0.3
B:					
Contained	1-1000	40.3	2.3	6.3	0.0
0.5%	1-10,000	2.3	0.7	4.7	0.0
Parathion	1-100,000	0.7	0.0	0.0	0.0
	1-1,000,000	0.7	0.0	0.0	0.0
C:					
Contained	1-1000	0.0	2.0	0.0	0.0
5.0%	1-10,000	0.0	0.0	0.0	0.0
Parathion	1-100,000	0.0	0.0	0.0	0.0
	1-1,000,000	0.0	0.0	0.0	0.0

[a] Each value is average of counts observed on three 100 mm petri dishes. Sampled from top one inch of soil.

[b] Topical application of 45.5% emulsifiable concentrate parathion 2 years earlier. Innoculum from this plot included to determine if any microorganisms subjected to parathion in soil for a two-year period had developed a detectable resistance to the pesticide.

also considerably higher than those for the treated plot. Counts for the plot treated with parathion 5 years earlier were much lower than the control, indicating that growth of microorganisms was still being inhibited to some extent after this period of time.

It should be pointed out that the counts shown in Tables 2 and 3 are not comparable since isolations were made in different years and at different times of the year.

In the above studies disappearance of parathion from soil occurred at a much slower rate than one might have expected, considering the year-around exposure to the natural elements. This was especially true in the experimental plots where the highly concentrated formulation was involved.

Many factors undoubtedly affected the disappearance of parathion from the soil, such as adsorption onto soil particles, volatilization, leaching, photochemical decomposition, chemical decomposition, and microbiological degradation, to name a few. Under conditions of this study adsorption undoubtedly played an important role. Leaching apparently was minimal. We did not attempt to determine loss from volatilization.

Findings reported in the present paper emphasize that when a high concentration of parathion is present as a result of spillage on soil it may persist for a long period of time and thus should be dug up and disposed where it will not be a hazard to small children or animals, and will not be available on the surface to contaminate the environment.

Acknowledgements

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References

1. CHISHOLM, D., MacPHEE, A. and MacEACHERN, C., Can. J. Agr. Sci. 35, 433 (1955).

2. EDWARDS, C., Soils and Fert. 6, 451 (1964).

3. STEWART, D., CHISHOLM, D. and RAGAB, M., Nature 229, 47 (1971).

4. WOLFE, H. and DURHAM, W., Wash. State Hort. Assoc. Proc. 62, 91 (1966).

5. AVERELL, P. and NORRIS, M., Anal. Chem. 20, 753 (1948).

6. ELLIOTT, J., WALKER, K., PENICK, A. and DURHAM, W., Agr. Food Chem. 8, 37 (1960).

7. QUINBY, G. and CLAPPISON, G., Arch. Environ. Health 3, 538 (1961).

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PESTICIDES IN SOIL

PESTICIDE PUBLICATION
690
Environmental Protection Agency

Pesticide Residue Levels in Soils and Crops, FY-70—National Soils Monitoring Program (II)

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P. F. Sand,[3] and Ann E. Carey [4]

ABSTRACT

This data report is a summary of Fiscal Year 1970 results of the National Soils Monitoring Program. It includes data on pesticide applications, soil residues, and crop residues collected from 1,506 cropland sites in 35 States. Pesticide application data are summarized by all sites and by State. Soil residue data are itemized similarly, but also include data by cropping region. Tables generally give the number of sites, number of times a pesticide was applied or detected, percent occurrence, arithmetic mean application rate or residue level, and range of residues detected. For some data, geometric means or 50 percentile levels, both with 95 percent confidence intervals, are presented.

Pesticides applied most frequently were atrazine, 2,4-D, captan, and malathion. Farmers in cotton and corn cropping regions applied the most pesticides; those in grass hay and mixed hay areas applied the least. Dieldrin, DDTR, aldrin, chlordane, and heptachlor epoxide were the chlorinated hydrocarbon residues found in soil most frequently. Highest residue levels were found in the corn and cotton cropping regions; lowest levels were in the hay, general farming, and small-grain soils.

Introduction

The National Soils Monitoring Program is an integral part of the National Pesticide Monitoring Program (NPMP). The Program was initiated at the recommendation of the President's Science Advisory Committee report of 1964 entitled "Use of Pesticides." This committee recommended that appropriate Federal agencies "develop a continuing network to monitor residue levels in air, water, soil, man, wildlife, and fish" (*1*).

The objective of NPMP is to determine levels and trends of pesticides and their degradation products in the various components of the environment (*2*). The initial goal, establishment of NPMP baseline or background levels of pesticide residues, will provide a basis for comparison of subsequently identified pesticide residue levels in an environmental component and, ultimately, detection of significant trends.

In determining levels and trends of pesticide residues, NPMP personnel have been guided by criteria of the Monitoring Panel of the Federal Working Group on Pest Management (*2*). The Panel has listed five areas of concern for individuals evaluating pesticide residue levels in environmental components. They are: any concentration of a pesticide known to be potentially harmful; increasing trends; levels exceeding standards; recognition of adverse effects on humans; and erratic variability, a statistically oriented observation that is potentially common to each stratum sampled.

This report is a summary of the pesticide application data and soil and crop residue data collected in Fiscal Year 1970 (FY-70) from 1,506 sites located in 35 States. Data were not collected from certain agricultural States because of budgetary limitations. States omitted were those abounding in wheat and other grains, which require fewer pesticides than do many nongrain crops. The FY-69 (*3*) and FY-70 findings have achieved the initial NPMP goal of establishing baseline data. Authors will identify significant trends as more data are accumulated.

Sampling

Sampling techniques involved in this study were generally the same as those employed by Wiersma, Sand, and Cox in a 1971 study (*4*). In FY-70, cropland sites in 35 States were sampled (Fig. 1). This included all but the following States: Alaska, Arizona, Colorado, Hawaii, Idaho, Kansas, Montana, Nevada, New Mex-

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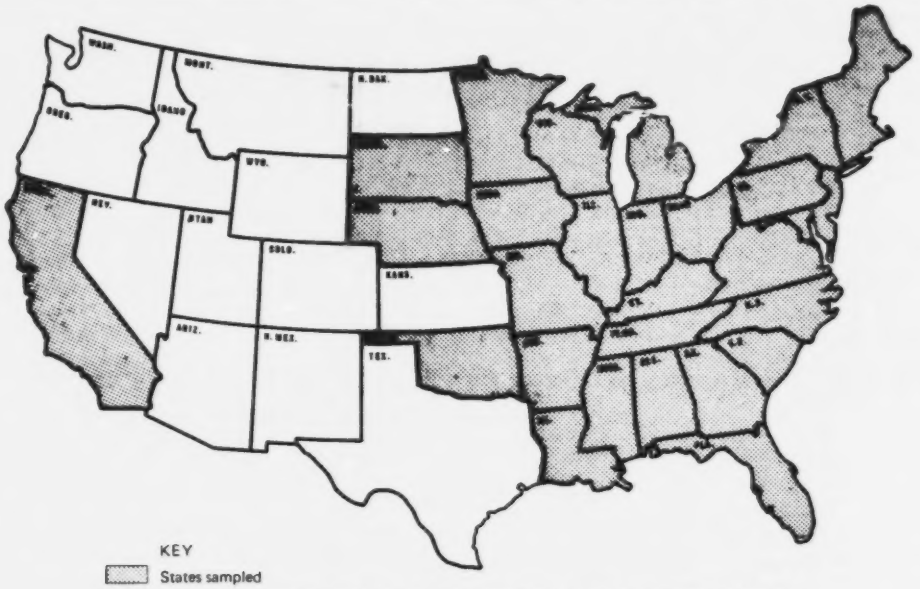

NOTE: In the FY-70 study, smaller Eastern States were combined to obtain a more reasonable sample. Such State groups represent unmarked areas on the maps. They are:

–Mid-Atlantic: Delaware, Maryland, and New Jersey
–New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont
–Virginia and West Virginia

FIGURE 1. *States sampled for pesticide residues, FY-70*

ico, North Dakota, Oregon, Texas, Utah, Washington, and Wyoming.

Although an attempt was made to collect soil and crop samples just prior to harvest, this was not always possible. Crop samples were not collected if the crop was not mature and/or ready for harvest.

Analytical Procedures

SOIL

To analyze soil for pesticide residues, a 300-g subsample was taken from a thoroughly mixed field sample. The subsample was dampened with water and extracted with 600 ml of 3:1 hexane:isopropanol solvent by concentric rotation for 4 hours. The isopropanol was removed by three distilled water washes and the hexane extract was dried through anhydrous sodium sulfate. The sample extract was then stored at low temperature for subsequent gas-liquid chromatographic analysis.

CROPS

To analyze crop samples containing less than 2 percent fat (e.g., alfalfa, bur clover, corn stalks, cotton stalks, green bolls, and miscellaneous hay), technicians blended 100-g samples of the crop with 25 ml of distilled water for 3 minutes in 800 ml of acetonitrile. Half the sample extract, containing 50 grams of the original sample, was decanted into a 500-ml Erlenmeyer flask. After concentration under a three-ball Snyder column to approximately 10 ml, 100 ml of hexane was added, and the hexane-acetonitrile azeotrope was again concentrated to 10 ml. This process was carried out three times to remove essentially all the acetonitrile. The hexane extract was dried through anhydrous sodium sulfate, the volume was adjusted to 100 ml, and the extract was stored at low temperature until ready for partitioning.

To analyze crop samples containing more than 2 percent fat (e.g., corn kernels, cottonseeds, and soybeans), researchers prewashed a 100-g sample with 100 ml of isopropanol and then with 100 ml of hexane. Both prewashes were discarded. The sample was dried, dry-blended, added to 100 ml isopropanol, and blended again. After the addition of 300 ml of hexane, the isopropanol was removed by two washes with aqueous NaCl solution and one wash with distilled water. The water-alcohol layers were discarded; the hexane layer was concentrated, adjusted to 100 ml, and held at low temperature for partitioning.

After extraction, all crop samples were partitioned with hexane-acetonitrile as follows: a 50-ml portion of

the hexane sample extract was shaken with 100 ml of acetonitrile in a 500 ml separatory funnel. The bottom acetonitrile layer was set aside. Nanograde acetonitrile (100 ml) was added to the hexane extract and the separation step described above was repeated two more times; then the hexane was discarded and the three acetonitrile layers were combined. The 300-ml acetonitrile extract, which contained essentially all the pesticides in the original hexane extract, was backwashed with 25 ml of acetonitrile-saturated hexane and the hexane layer was discarded. The acetonitrile sample extract was concentrated to approximately 10 ml under a three-ball Snyder column, and 100 ml of hexane was added. Addition of hexane and concentration to approximately 10 ml was performed three times, after which the sample was essentially in hexane. Remaining hexane extract was diluted to appropriate volume and held at low temperature for subsequent florisil column cleanup and fractionation.

GAS-LIQUID CHROMATOGRAPHY

Analyses were performed on gas chromatographs equipped with tritium foil electron affinity detectors for organochlorine compounds and thermionic or flame photometric detectors for organophosphorous compounds. A multiple-column system employing polar and nonpolar columns was utilized to identify and confirm pesticides. Instrument parameters were as follow:

Columns:	Glass, 6 mm o.d. by 4 mm i.d., 183 cm long, packed with one of the following: 9 percent QF-1 on 100/120 mesh Gas-Chrom Q; 3 percent DC-200 on 100/120 mesh Gas-Chrom Q; or 1.5 percent OV-17/1.95 percent QF-1 on 100/120 mesh Sepulcoport.	
Carrier Gases:	5 percent methane-argon at a flow rate of 80 ml/min; prepurified nitrogen at a flow rate of 80 ml/min.	
Temperatures:	Detector	200°C
	Injection port	250°C
	Column QF-1	166°C
	Column DC-200	170-175°C
	Mixed column	185-190°C

Sensitivity or minimum detection levels for organochlorine compounds ranged from 0.002 to 0.03 ppm except for combinations of polychlorinated biphenyls (PCB's), chlordane, toxaphene, and other chemicals which had minimum detectable levels of 0.05 to 0.1 ppm. Minimum detectable levels for organophosphorous compounds were approximately 0.01 to 0.03 ppm. When necessary, residues were confirmed by thin-layer chromatography or p-values.

RECOVERY STUDIES

For organochlorine pesticides, average recovery rate in soil was 90 to 110 percent. Recovery values for stalks and hay ranged from 80 to 95 percent, with an average of 89 percent; corresponding values for grains were 90 to 100 percent, with a 95 percent average. For organophosphate pesticides, average recovery values were 67.1 percent for soybeans, 86 percent for sorghum grain, and 60 percent for corn stalks. Residue levels in both crops and soils are expressed on a dry-weight basis and are corrected for percent recovery.

Results

Tables presented in this report are divided into three groups: pesticides applied to cropland, chlorinated hydrocarbon pesticide residues in cropland soil, and chlorinated hydrocarbon and organophosphate pesticide residues in crops. Pesticide application data are further subdivided by all sites and by State. Residues in soil are summarized by all sites and by States and cropping regions.

Most tables list the number of samples, the number of times a pesticide was applied or detected, percent occurrence of that particular pesticide, arithmetic mean, and range. Readers should exercise caution when interpreting the arithmetic mean because data are not normally distributed. The arithmetic mean tends to be considerably higher than the corresponding median; but because of the skewed distribution of these data, the mean may not be a good indication of central tendency. Hence geometric means and 50 percent estimates have been presented.

PESTICIDES APPLIED TO CROPLAND

When soil samples were collected from cropland, field personnel attempted to contact farmers to determine what pesticides had been applied to the sites during the year of sampling. These data were not always available: only 1,346 use records were collected from 1,506 sites. Tables summarizing application data show the number of sites using a pesticide, percent of sites using a particular pesticide, average rate of application for sites using the pesticide, and average amount of pesticide applied to all sites. The latter figure was determined by dividing the total amount of active ingredients applied to all sites by the total number of sites surveyed. All rate data are expressed in pounds per acre (lb/a). To convert to kilograms per hectares (kg/ha), multiply by 1.1208.

ALL SITES

Table 1 is a summary of the 1,346 sites surveyed from 35 States. The most common pesticides were atrazine, 2,4-D, captan, and malathion, which were used

on 11, 9, 8, and 6 percent of the sites, respectively. Aldrin and DDT were used on 4 percent of the sites.

BY STATE

Table 2 is a breakdown of the all-site data by State. Because some of the smaller Eastern States had very few samples, several were combined to obtain more representative data. State groups used were Mid-Atlantic: Delaware, Maryland, and New Jersey; New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont; and Virginia and West Virginia.

Considering the number of States sampled, it is not feasible to discuss pesticide applications of each State. It is, however, worthwhile to mention application frequencies of a few States.

Because Mississippi farmers produce large quantities of cotton, a crop which demands heavy pesticide treatment, they apply a large number of pesticides to much of their cropland. Growers used the following pesticides most frequently on the specified percentage of sites: methyl parathion, 48 percent; trifluralin, 42 percent; DDT, 32 percent; Cotoran (fluometuron), 26 percent; toxaphene, 23 percent; Bidrin (dicrotophos), 19 percent; MSMA, 19 percent; folex, 16 percent; and diuron, 13 percent. In Illinois, a major corn-growing State, pesticides applied most frequently and the percentage of sites treated were: captan, 45 percent; malathion, 45 percent; Ramrod (propachlor), 24 percent; aldrin, 18 percent; atrazine, 16 percent; and heptachlor, 12 percent. In contrast to these States were Oklahoma, Minnesota, Kentucky, and the New England group, where no pesticide was applied to more than 8 percent of the sampling sites.

Herbicide 2,4-D was applied most frequently in South Dakota; of the sites sampled, 25 percent were treated. Atrazine was applied most frequently in Wisconsin and North Carolina: 25 and 26 percent of the sites, respectively, were treated. Captan was applied most frequently in the Mid-Atlantic States; 47 percent of the sites were treated.

BY CROP

Table 3 presents pesticide application data for several crops. The few pesticides applied to alfalfa and bur clover were not widely used. Of the many different pesticides applied to field corn, atrazine, captan, 2,4-D, and malathion were employed most frequently. Farmers used 45 different pesticides on cotton fields; of these compounds, 14 were applied to more than 10 percent of the sites. In contrast, field workers applied only two pesticides to both grass hay and mixed hay fields. Although 27 pesticides were applied to soybeans, only amiben and trifluralin were applied to more than 5 percent of the sites sampled.

CHLORINATED HYDROCARBON PESTICIDE RESIDUES IN CROPLAND SOIL

All 1,506 soil samples from the 35 States were examined for chlorinated hydrocarbon residues. A few samples were analyzed for additional pesticides, but these data were insufficient for consideration. In the future, soil residue analyses will be expanded to include more compounds.

Samples were not analyzed for PCB's because little was known about them at the time of analysis. A review of the gas chromatograph traces revealed that PCB residues were seldom present and, when they were, the residues existed only in very small quantities. PCB peaks were recognized and not confused with DDT.

ALL SITES

Table 4 summarizes chlorinated hydrocarbon soil residue data for all States, including the number of times a pesticide was detected, percent occurrence, arithmetic mean, geometric mean with 95 percent confidence interval, and range of detected residue values. The geometric mean was used because it gives a better indication of the central tendency of the data. It was calculated using a 0.01 addition to eliminate the problem of zeros and was later subtracted from the calculated mean.

The most widely distributed chlorinated hydrocarbon was dieldrin: 31 percent of the soil samples had detectable residues. It was followed by DDTR (DDE+TDE), aldrin, chlordane, and heptachlor epoxide, which were detected at 23, 13, 11, and 10 percent of the sites, respectively.

DDTR existed in the highest concentration, with an arithmetic mean of 0.30 ppm and geometric mean of 0.0116 ppm. Although the arithmetic mean for dieldrin was much lower than that for DDTR, the geometric means are indistinguishable at the 95 percent confidence level. The very high residue value of 113 ppm as shown in the range of DDTR can have a major effect on an arithmetic mean. The effect of extreme values upon the geometric mean is considerably less.

BY STATE

Chlorinated hydrocarbon residues in soils of specific States (Table 5) are presented in the same manner as the all-sites data except for the geometric means.

Comparisons of the percent occurrence of aldrin, dieldrin, heptachlor epoxide, DDTR, and chlordane are presented in Figures 2 through 6. The key for each figure is based on the arithmetic average percent occurrence ($\bar{x}$) of the given pesticide for all sites. The four categories used are: greater than $2\bar{x}$, greater than $\bar{x}$ but less than $2\bar{x}$, greater than $\frac{1}{2}\bar{x}$ but less than $\bar{x}$, and less than $\frac{1}{2}\bar{x}$.

Iowa and Illinois showed the highest percent occurrence of aldrin, dieldrin, and heptachlor epoxide (Fig.

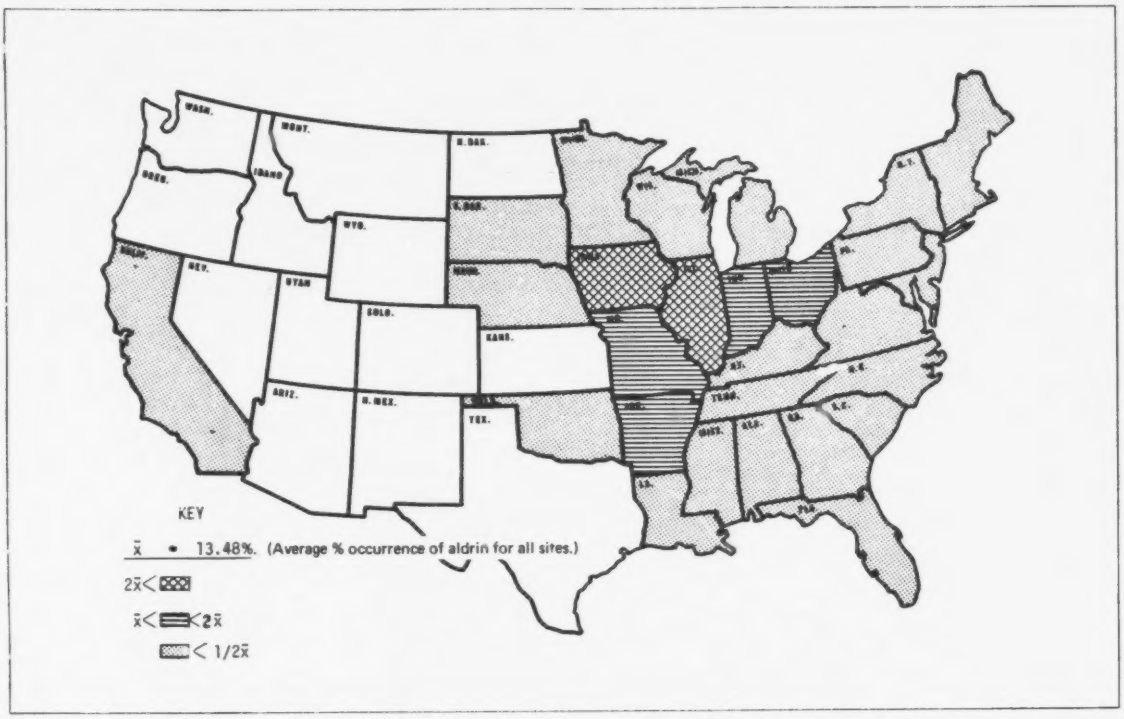

FIGURE 2. *Aldrin residues, %, in cropland soil by State, FY-70*

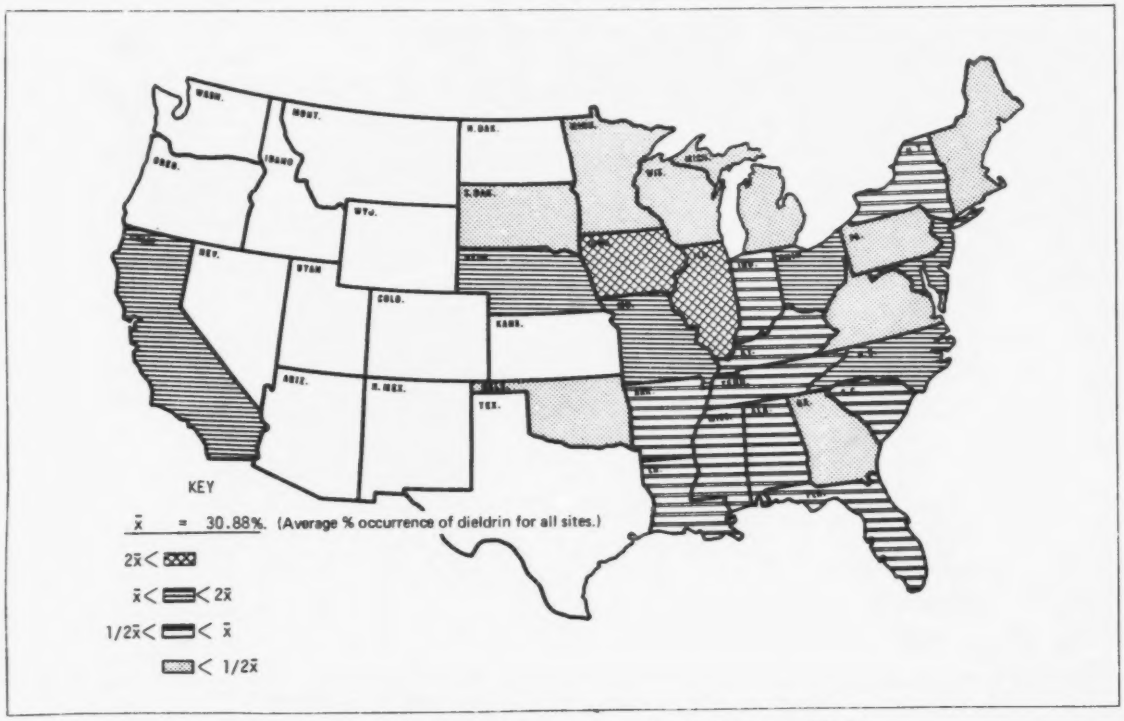

FIGURE 3. *Dieldrin residues, %, in cropland soil by State, FY-70*

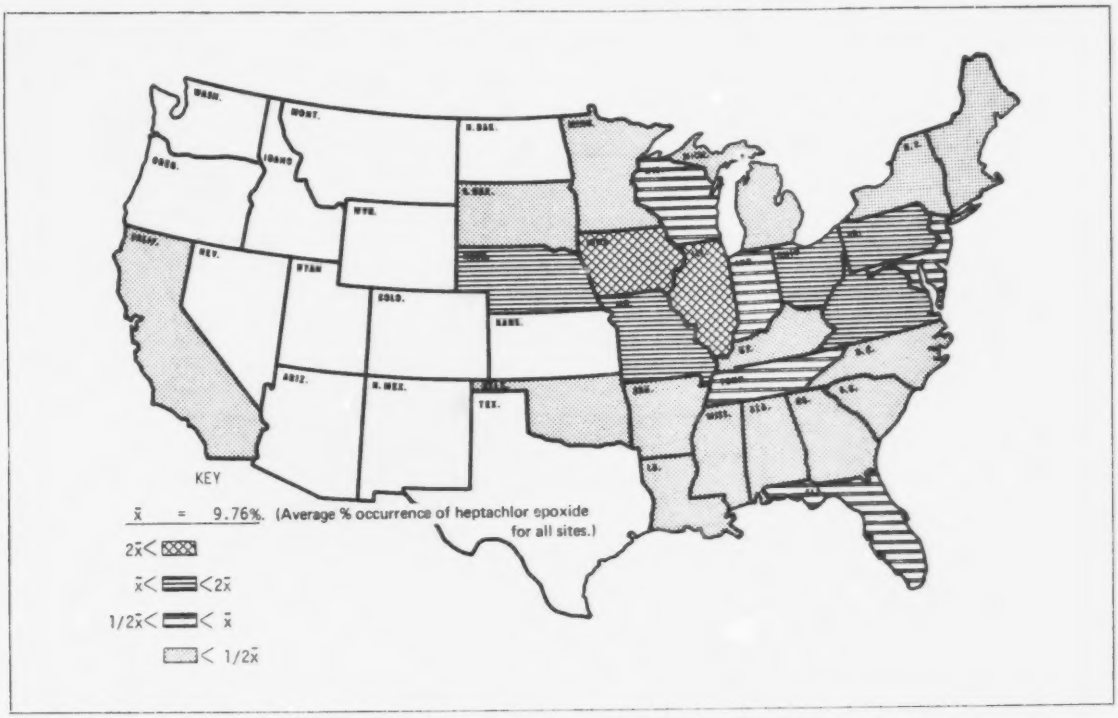

FIGURE 4. *Heptachlor epoxide residues, %, in cropland soil by State, FY-70*

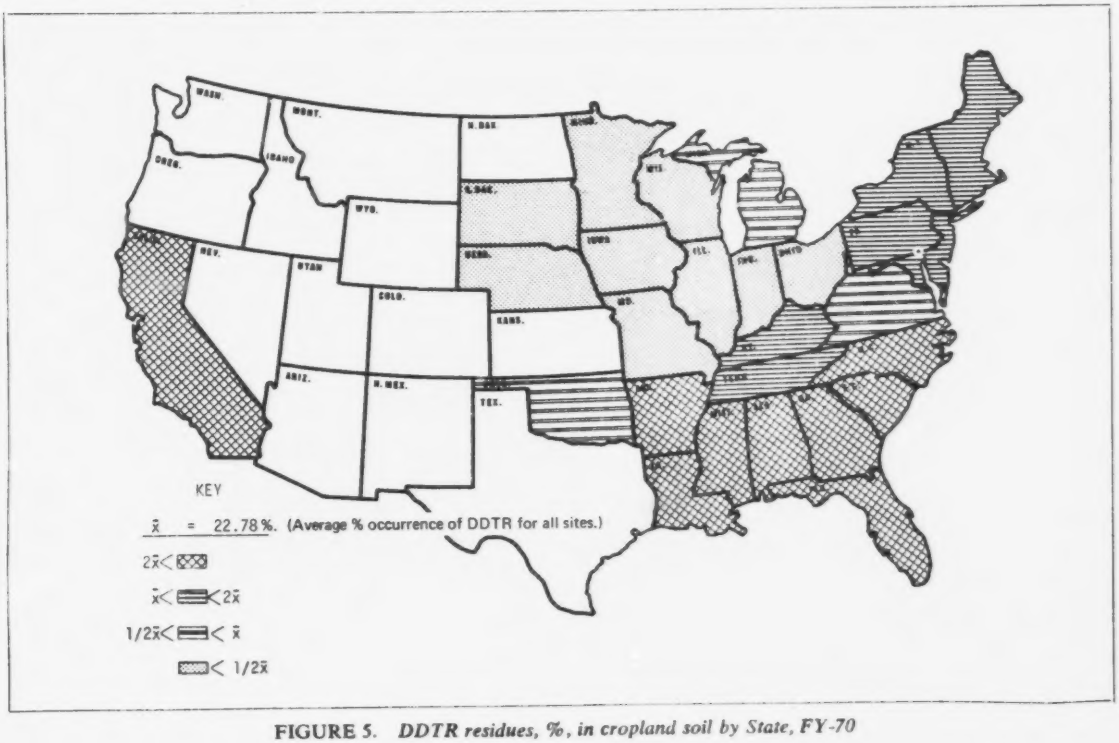

FIGURE 5. *DDTR residues, %, in cropland soil by State, FY-70*

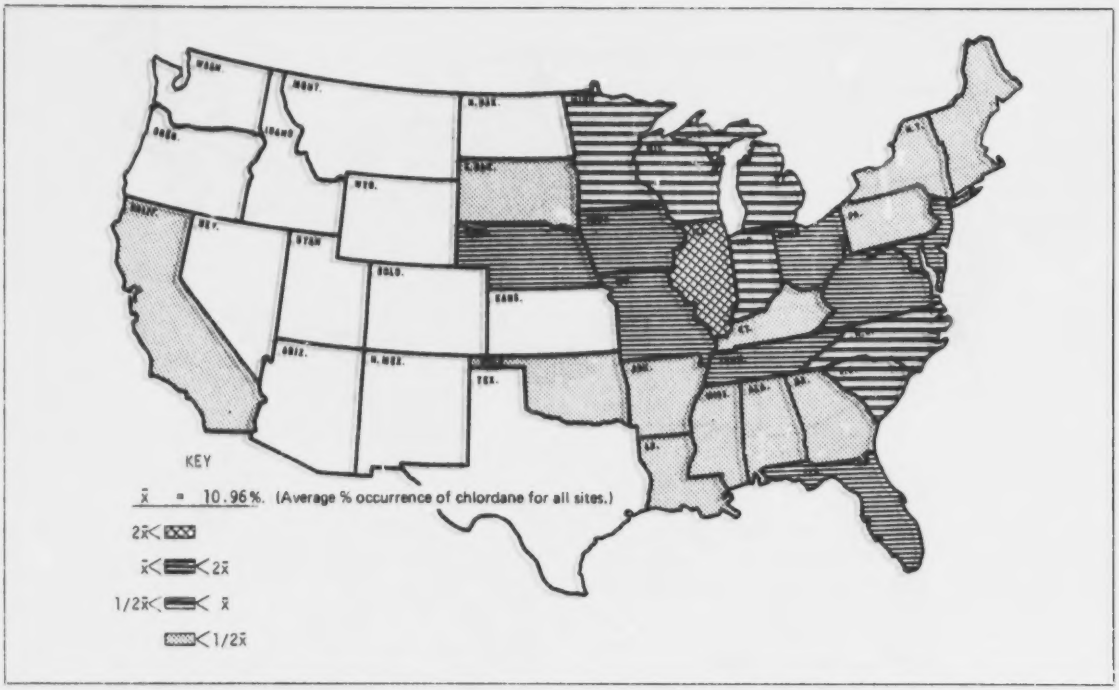

FIGURE 6. *Chlordane residues, %, in cropland soil by State, FY-70*

2-4). DDTR detections were concentrated in Southeastern States and California (Fig. 5); Central States showed low incidence. Chlordane occurred most frequently in Illinois soil samples (Fig. 6).

Michigan, Minnestoa, Oklahoma, and Wisconsin were below the all-sites average detection frequency for all five pesticides. Residue levels in South Dakota were less than half the comparable all-sites figures.

Table 6 lists the 50 percent estimates and 95 percent confidence interval of that estimate, offering a statistical comparison of pesticide residue levels between States. The given values were calculated using a slightly modified regression analysis method described by Daum (5). Residue values were ranked from lowest to highest and accumulated; percentages were then computed. Values were transformed to logarithms, percentages were transformed to probits, and the relationship between the logarithms and probits was calculated by regression analysis. Six different detectable residue levels were required for the calculation. When the upper limit of the 95 percent fiducial interval is less than 0.01 ppm, no value is shown.

BY CROPPING REGION

Data were grouped into cropping regions based upon a major land use map of the United States compiled by F. J. Marschner, U.S. Department of Agriculture, Bureau of Agricultural Economics, 1950. The land in the United States was grouped by county into several major land use areas: corn, cotton, fruit, general farming, hay, small grain, and vegetables. In some cases, two areas overlapped: cotton and general farming, for example (Fig. 7). Field personnel determined at the time of sample collection whether land had been irrigated.

The percent occurrence and arithmetic means for soil residues by cropping region are presented in Tables 7 and 8. In the corn region, aldrin, chlordane, and dieldrin residues were widespread and the mean concentrations for these pesticides were also above the all-sites average. Cotton region soils had high DDTR, toxaphene, and trifluralin residues. A greater variety of pesticides was detected in the cotton and general farming region than in the cotton region, but residue values and percent occurrence of comparable pesticides were usually lower. Hay and general farming residues were lower and small-grain soils generally contained the lowest residue levels. The number of sites in irrigated land, vegetable and fruit, and vegetable regions was small; data appear to indicate widespread occurrence of DDT residues.

Table 9 lists the 50 percent estimate and 95 percent confidence interval of that estimate for pesticide residues in soil by cropping region. Using this table makes it possible to determine whether two residue values are significantly different with a risk of less than 5 percent.

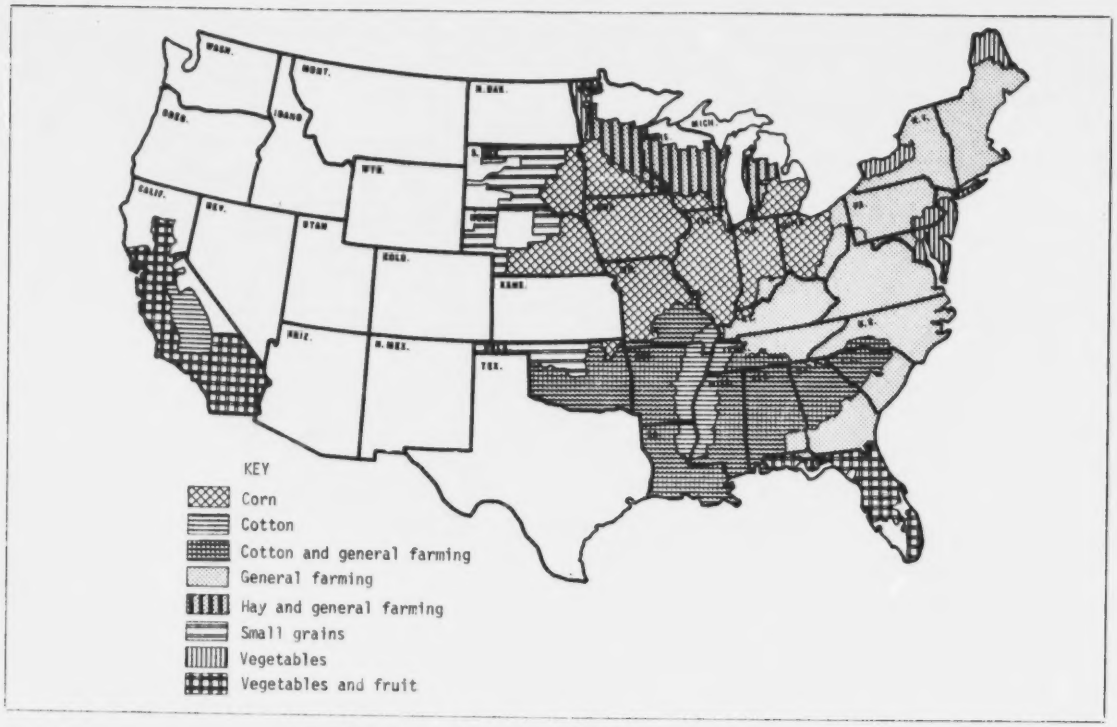

FIGURE 7. *Cropping regions for States sampled, FY-70*

When the confidence interval for DDTR for cotton is higher and does not overlap with the DDTR interval for cotton and general farming, it can be stated that the cotton region has higher DDTR residues in cropland soil than the cotton and general farming region with less than a 5 percent risk.

Table 9 indicates that DDTR residues were found principally in cotton, vegetable and fruit, and irrigated land regions; corn, hay, and vegetable regions were relatively free of this residue. Significantly high dieldrin residues were associated with corn and irrigated land regions.

BY CROP

Pesticide residues in soil have also been grouped according to crops grown on the soil (Table 10). The few minor discrepancies between the number of sites examined in Tables 3 and 10 are due to lost samples.

Soils under alfalfa and bur clover contained a number of low-level pesticide residues. Field corn soils showed detectable levels of dieldrin at 42 percent of the sites. Soil in cotton fields averaged over 2 ppm DDTR. Although very few pesticides were applied to grass hay or mixed hay sites, the occurrence of detectable residues of dieldrin and DDTR was surprisingly high. Dieldrin was the residue found most commonly in soybean soils, but DDTR was the residue in highest concentration.

CHLORINATED HYDROCARBON AND ORGANOPHOSPHATE PESTICIDE RESIDUES IN CROPS

As mentioned earlier, crop samples were collected only from crops which were ripe and/or ready for harvest. They were taken directly from the field and were collected whenever available. In total, 952 samples were collected from about 640 sites. All crop samples were analyzed for chlorinated hydrocarbon pesticides. In addition, samples were analyzed for organophosphates when use records indicated they had been applied. The organophosphate sample is thus biased and could be expected to yield higher residue values for any given crop than would have resulted had all samples been analyzed.

Alfalfa and bur clover samples contained DDTR 28 percent of the time (Table 11); chlordane and dieldrin were detected less frequently. Most of these samples were analyzed for organophosphate residues; no such residues were detected.

Field corn kernels were exceptionally free of both chlorinated hydrocarbon and organophosphate pesticide residues. However, pesticide residues in field corn stalks were detected considerably more often. DDTR, dieldrin,

and chlordane occurred 20, 16, and 5 percent of the time, respectively; detected concentrations were low.

Cottonseeds were frequently contaminated with DDTR, toxaphene, DEF, and methyl parathion. Cotton stalks contained high concentrations of pesticides: DDTR was found in 91 percent of the stalk samples with an average concentration of 3.81 ppm; toxaphene occurred in 45 percent of the samples and averaged 6.96 ppm; dieldrin occurred frequently, but the residue levels were much lower. Of the 18 sites where organophosphates were applied to cotton, methyl parathion occurred 50 percent of the time. DEF, malathion, and ethyl parathion occurred 39, 22, and 17 percent of the time, respectively. Concentrations of both ethyl parathion and DEF were relatively high.

Grass hay contained a number of pesticides, but the frequency of any single pesticide was less than 11 percent. DDTR was the only pesticide with a significant level of occurrence, but even it had a low average-residue level: 0.07 ppm.

Mixed hay contained no detectable organophosphate residues, but frequently contained chlorinated hydrocarbons. DDTR was again the most prevalent pesticide, occurring 69 percent of the time. Chlordane and toxaphene were also found but, like DDTR, at low concentrations.

Soybeans showed traces of dieldrin in 39 percent of the samples, but no pesticide exceeded an average concentration of 0.03 ppm. Soybeans showed no organophosphate residues even though all 137 sites sampled had been treated with such pesticides.

Acknowledgments

It is not possible to list by name all persons who contributed to this study. However, authors are especially grateful to the staff at the Monitoring Laboratory, Mississippi Test Facility, Bay St. Louis, Miss., who processed and analyzed samples for chemical residues and contributed immeasurably to this study, and to inspectors from the Animal and Plant Health Inspection Service, USDA, who collected the samples. Finally, recognition is due Dr. Edwin Cox, Biometrical Services Staff, USDA, for sample allocation procedures, and to Dr. Richard Daum, Animal and Plant Health Inspection Service, for probit analyses.

Literature Cited

(1) *Bennett, I. L. 1967.* Foreword. Pestic. Monit. J. 1(1).
(2) *Panel on Pesticide Monitoring. 1971.* Criteria for defining pesticide levels to be considered an alert to potential problems. Pestic. Monit. J. 5(1):36.
(3) *Wiersma, G. B., H. Tai, and P. F. Sand. 1972.* Pesticide residue levels in soil, FY 1969—National Soils Monitoring Program. Pestic. Monit. J. 6(3):194-201.
(4) *Wiersma, G. B., P. F. Sand, and E. L. Cox. 1971.* A sampling design to determine pesticide residue levels in soils of the conterminous United States. Pestic. Monit. J. 5(1):63-66.
(5) *Daum, R. L. 1970.* Revision of two computer programs for probit analysis. Bull. Entomol. Soc. Am. 16:10-15.

TABLE 1. *Summary of pesticides applied to cropland, all sites,[1] FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (lb/A)[2]	Arith. Mean (lb/A)[2]
Aldrin	57	4.23	1.03	0.0434
Amiben	51	3.79	1.77	0.0669
Amitrole	1	0.07	2.11	0.0016
Atrazine	154	11.44	1.74	0.1987
Azinphosmethyl	15	1.11	4.19	0.0467
Azodrin (monocrotophos)	6	0.45	4.28	0.0191
Barban	1	0.07	0.20	0.0001
Benefin	2	0.15	1.31	0.0019
Bidrin (dicrotophos)	8	0.59	0.31	0.0018
Borax	2	0.15	1.25	0.0019
Bordeaux mixtures	1	0.07	1.00	0.0007
Buturon	2	0.15	0.01	0.0000
Bux-ten (bux)	16	1.19	2.27	0.0269
Calcium arsenate	1	0.07	9.80	0.0073
Captan	106	7.88	1.68	0.1323
Carbaryl	31	2.30	3.91	0.0900
Carbophenothion	3	0.22	0.92	0 0020
CDAA	1	0.07	0.60	0.0004
CDEA	1	0.07	2.00	0.0015
Ceresan L	3	0.22	0.04	0.0001
Ceresan M (granosan)	8	0.59	0.02	0.0001
Ceresan red	19	1.41	0.03	0.0004
Chevron RE-5353	1	0.07	0.70	0.0005
Chlordane	1	0.07	1.00	0.0007
Chlorobenzilate	3	0.22	0.95	0.0021
Chloroneb	5	0.37	0.01	0.0000
Chloroxuron	3	0.22	1.42	0.0032
CIPC (chloropropham)	1	0.07	0.66	0.0005
Copper oxide	3	0.22	3.70	0.0082
Copper-8-quinolinolate	1	0.07	0.01	0.0000
Copper sulfate	9	0.67	56.65	0.3788
Cotoran (fluometuron)	15	1.11	0.68	0.0076
2,4-D	122	9.06	0.64	0.0578
DAC	3	0.22	3.50	0.0078
Dalapon	10	0.74	2.55	0.0189

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TABLE 1 (cont'd). *Summary of pesticides applied to cropland, all sites,[1] FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Appl. Rate Arith. Mean (lb/a)[2]	Arith. Mean (lb/a)[2]
2,4-DB	7	0.52	0.56	0.0029
DDT	37	3.75	5.20	0.1428
DEF	6	0.45	1.44	0.0064
Demeton	2	0.15	0.88	0.0013
Diazinon	11	0.82	1.95	0.0160
Dicamba	2	0.15	0.04	0.0001
Dichloropropane	1	0.07	26.00	0.0193
Dichloropropene	2	0.15	64.21	0.0954
Dichlorprop	1	0.07	0.50	0.0004
Dicofol	4	0.30	1.95	0.0058
Dieldrin	5	0.37	0.21	0.0008
Dimethoate	2	0.15	3.21	0.0048
Dinitrobutylphenol	6	0.45	2.84	0.0126
Dinitrocresol	2	0.15	0.10	0.0002
Dinitrocyclohexylphenol	1	0.07	0.50	0.0004
Dioxathion	1	0.07	0.75	0.0006
Diphenamid	2	0.15	3.00	0.0045
Disulfoton	11	0.82	0.62	0.0050
Dithane M-45 (mancozeb)	1	0.07	1.50	0.0011
Diuron	8	0.59	0.47	0.0028
Dodine	3	0.22	5.23	0.0117
DSMA	6	0.45	2.02	0.0090
Endosulfan (I)	3	0.22	0.61	0.0014
Endothall	1	0.07	0.90	0.0007
Endrin	6	0.45	2.28	0.0102
EPN	2	0.15	1.10	0.0016
EPTC	5	0.37	22.10	0.0821
Ethion	8	0.59	2.13	0.0126
Ethylene dibromide	1	0.07	0.01	0.0000
Falone	1	0.07	2.00	0.0015
Fensulfothion	4	0.30	1.20	0.0036
Fenthion	1	0.07	0.09	0.0001
Ferbam	1	0.07	4.60	0.0034
Folex	7	0.52	1.30	0.0068
Furadan (carbofuran)	1	0.07	1.00	0.0007
Heptachlor	20	1.49	0.79	0.0118
Isopestox	1	0.07	0.01	0.0000
Lasso	13	0.97	1.01	0.0098
Lead arsenate	1	0.07	6.40	0.0048
Lindane	4	0.30	0.01	0.0000
Linuron	15	1.11	0.86	0.0096
Malathion	84	6.24	0.19	0.0117
Maleic hydrazide	3	0.22	1.80	0.0040
Maneb	2	0.15	1.00	0.0015
MCPA	10	0.74	0.66	0.0049
Methoxychlor	22	1.63	0.12	0.0020
Methyl demeton	2	0.15	1.13	0.0017
Methylmercury dicyandiamide	14	1.04	0.01	0.0001
Methyl trithion	2	0.15	7.75	0.0115
Mevinphos	2	0.15	0.10	0.0001
Mirex	1	0.07	0.01	0.0000
Monuron	2	0.15	0.31	0.0005
MSMA	13	0.97	1.79	0.0173
Nitralin	7	0.52	0.75	0.0039
Nitrate	7	0.52	51.71	0.2689
Norea	2	0.15	1.00	0.0015
NPA	6	0.45	2.02	0.0090
Paraquat	6	0.45	0.18	0.0008
Parathion, ethyl	20	1.49	3.41	0.0507
Parathion, methyl	44	3.27	4.16	0.1360
PCNB	3	0.22	0.01	0.0000
Phorate	19	1.41	3.17	0.0447
Picloram	1	0.07	1.00	0.0007
Prometryne	1	0.07	0.75	0.0006
Propanil	3	0.22	2.83	0.0063
Ramrod (propachlor)	45	3.34	1.47	0.0493
Silvex	5	0.37	0.64	0.0024
Simazine	5	0.37	2.66	0.0099
Sodium chlorate	5	0.37	6.40	0.0238
Strobane	1	0.07	3.00	0.0022
Sulfur	16	1.19	50.74	0.6032
Sutan	5	0.37	3.95	0.0147
2,4,5-T	1	0.07	2.00	0.0015
TCA	2	0.15	5.25	0.0078
TDE	6	0.45	2.38	0.0106
Terbacil	2	0.15	0.39	0.0006
Tetradifon	1	0.07	0.75	0.0006
Thiram	7	0.52	0.02	0.0001
Toxaphene	33	2.45	9.54	0.2339
Trifluralin	47	3.49	0.94	0.0330
Vernolate	7	0.52	2.90	0.0151

[1] 1,346 sites, 35 States.

[2] To convert lb/a to kg/ha., multiply by 1.1208.

TABLE 2. *Pesticides applied to cropland by State, FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (lb/a)[1]	Arith. Mean (lb/a)[1]
Alabama, 22 Sites				
Azinphosmethyl	1	4.55	4.00	0.1818
Azodrin	1	4.55	12.00	0.5455
Copper sulphate	1	4.55	8.00	0.3636
Cotoran	2	9.09	1.50	0.1364
DDT	6	27.27	11.08	3.0227
DEF	1	4.55	1.50	0.0682
DSMA	1	4.55	2.00	0.0909
Endothall	1	4.55	0.90	0.0409
Endrin	1	4.55	10.50	0.4773
Nitralin	2	9.09	1.00	0.0909
Parathion, ethyl	3	13.64	16.06	2.1900
Parathion, methyl	7	31.82	6.54	2.0823
Strobane	1	4.55	3.00	0.1364
Sulfur	1	4.55	72.00	3.2727
Toxaphene	3	13.64	48.31	6.5873
Trifluralin	3	13.64	2.03	0.2773
Arkansas, 47 Sites				
Aldrin	1	2.13	0.01	0.0002
Amiben	2	4.26	1.00	0.0428
Azodrin	1	2.13	3.75	0.0798
Captan	2	4.26	0.03	0.0015
Carbaryl	3	6.38	1.70	0.1085
Ceresan M	2	4.26	0.05	0.0023
Ceresan red	2	4.26	0.10	0.0043
Chloroneb	3	6.38	0.01	0.0009
Cotoran	2	4.26	0.77	0.0330
Dalapon	1	2.13	3.00	0.0638
2,4-DB	2	4.26	0.50	0.0213
DDT	2	4.26	6.25	0.2660
DEF	1	2.13	0.75	0.0160
Dinitrobutylphenol	1	2.13	10.00	0.2128
Dinitrocyclohexylphenol	1	2.13	0.50	0.0106
DSMA	1	2.13	1.00	0.0213
EPN	1	2.13	0.50	0.0106
Ethylene dibromide	1	2.13	0.01	0.0002
Folex	2	4.26	1.50	0.0638
Lasso	1	2.13	0.50	0.0106
Linuron	1	2.13	1.50	0.0319
Methylmercury dicyandiamide	3	6.38	0.01	0.0006
Methyl trithion	1	2.13	5.50	0.1170
Monuron	1	2.13	0.25	0.0053
MSMA	3	6.38	3.33	0.2128
Nitralin	2	4.26	0.44	0.0187
Norea	1	2.13	1.00	0.0213
Paraquat	1	2.13	0.25	0.0053
Parathion, methyl	10	21.28	4.00	0.8511
Phorate	1	2.13	0.50	0.0106
Prometryne	1	2.13	0.75	0.1600
Propanil	1	2.13	2.50	0.0532
Toxaphene	2	4.26	1.75	0.0745
Trifluralin	9	19.15	0.68	0.1311
California, 43 Sites				
Azinphosmethyl	3	6.98	0.92	0.0640
Azodrin	2	4.65	4.38	0.2035
Bidrin	1	2.33	0.75	0.0174
Bordeaux mixtures	1	2.33	1.00	0.0233
Carbaryl	1	2.33	1.25	0.0291
Carbophenothion	1	2.33	0.50	0.0116
Chlorobenzilate	1	2.33	1.00	0.0233
2,4-D	1	2.33	0.88	0.0205
DAC	1	2.33	4.00	0.0930
DDT	3	6.98	3.00	0.2093
DEF	1	2.33	3.00	0.0698
Diazinon	1	2.33	2.00	0.0465
Dicofol	2	4.65	0.88	0.0407
Dimethoate	1	2.33	0.33	0.0077
Dioxathion	1	2.33	0.75	0.0174
Disulfoton	1	2.33	1.00	0.0233
DSMA	1	2.33	2.00	0.0465
Endosulfan (I)	2	4.65	0.88	0.0407
Endrin	1	2.33	0.75	0.0174
Ethion	2	4.65	1.50	0.0698
Fenthion	1	2.33	0.09	0.0021
Malathion	2	4.65	2.02	0.0942
Methyl demeton	1	2.33	0.25	0.0058
Paraquat	2	4.65	0.18	0.0086
Parathion, ethyl	7	16.28	0.99	0.1616
Parathion, methyl	1	2.33	0.10	0.0023
Simazine	2	4.65	3.30	0.1535
Sodium chlorate	3	6.98	8.17	0.5698

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TABLE 2 (cont'd). *Pesticides applied to cropland by State, FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (Lb/A)[1]	Arith. Mean (Lb/A)[1]
Sulfur	5	11.63	41.71	4.8502
Tetradifon	1	2.33	0.75	0.0174
Toxaphene	3	6.98	6.00	0.4186
Trifluralin	1	2.33	2.00	0.0465
Florida, 18 Sites				
Aldrin	1	5.56	4.44	0.2467
Atrazine	1	5.56	0.50	0.0278
Carbaryl	1	5.56	5.00	0.2778
Carbophenothion	2	11.11	1.13	0.1250
Chlorobenzilate	2	11.11	0.92	0.1022
Copper oxide	2	11.11	4.65	0.5167
2,4-D	1	5.56	2.00	0.1111
Dalapon	1	5.56	2.00	0.1111
Dicofol	1	5.56	2.00	0.1111
Dimethoate	1	5.56	6.10	0.3389
Ethion	5	27.78	2.30	0.6389
Lead arsenate	1	5.56	6.40	0.3556
Parathion, ethyl	2	11.11	3.55	0.3944
Sulfur	4	22.22	60.65	13.4778
2,4,5-T	1	5.56	2.00	0.1111
Toxaphene	1	5.56	4.00	0.2222
Georgia, 30 Sites				
Atrazine	2	6.67	2.70	0.1800
Azodrin	1	3.33	0.60	0.0200
Benefin	2	6.67	1.31	0.0873
Bidrin	1	3.33	0.30	0.0100
Calcium arsenate	1	3.33	9.80	0.3267
Captan	8	26.67	0.05	0.0147
Carbaryl	5	16.67	4.45	0.7417
Ceresan red	4	13.33	0.01	0.0013
Copper sulfate	8	26.67	62.73	16.7283
DDT	7	23.33	3.96	0.9233
Dinitrobutylphenol	2	6.67	1.50	0.1000
Disulfoton	1	3.33	0.80	0.0267
Dithane M-45	1	3.33	1.50	0.0500
DSMA	1	3.33	0.50	0.0167
Endrin	1	3.33	0.33	0.0110
Falone	1	3.33	2.00	0.0667
Linuron	1	3.33	1.00	0.0333
Malathion	4	13.33	0.01	0.0013
Methoxychlor	4	13.33	0.03	0.0040
Methyl trithion	1	3.33	10.00	0.3333
Mirex	1	3.33	0.01	0.0003
Parathion, methyl	2	6.67	1.02	0.0683
Simazine	1	3.33	2.50	0.0833
Sulfur	3	10.00	20.00	2.0000
Toxaphene	7	23.33	4.63	1.0800
Trifluralin	1	3.33	1.50	0.0500
Vernolate	5	16.67	2.20	0.3667
Illinois, 51 Sites				
Aldrin	9	17.65	0.92	0.1627
Amiben	5	9.80	2.60	0.2549
Atrazine	8	15.69	1.94	0.3049
Bux-ten (bux)	4	7.84	2.97	0.2333
Captan	23	45.10	0.03	0.0122
Carbaryl	1	1.96	2.00	0.0392
Ceresan red	2	3.92	0.01	0.0004
2,4-D	3	5.88	0.31	0.0182
DAC	1	1.96	1.50	0.0294
Dalapon	1	1.96	1.00	0.0196
Diazinon	2	3.92	0.50	0.0198
Dicamba	1	1.96	0.02	0.0004
Furadan	1	1.96	1.00	0.0196
Heptachlor	6	11.76	0.84	0.0984
Lasso	1	1.96	1.40	0.0275
Linuron	1	1.96	1.00	0.0196
Malathion	23	45.10	0.01	0.0045
Methoxychlor	5	9.80	0.01	0.0010
Phorate	1	1.96	0.05	0.0010
Ramrod	12	23.53	1.23	0.2904
Silvex	1	1.96	0.50	0.0098
Vernolate	1	1.96	1.30	0.0255
Indiana, 77 Sites				
Aldrin	7	9.09	0.82	0.0742
Amiben	6	7.79	0.97	0.0756
Atrazine	13	16.88	1.37	0.2318
Captan	11	14.29	0.01	0.0016
Ceresan red	1	1.30	0.02	0.0003
2,4-D	9	11.69	0.66	0.0769

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TABLE 2 (cont'd). *Pesticides applied to cropland by State, FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (lb/a)[1]	Arith. Mean (lb/a)[1]
Dinitrobutylphenol	1	1.30	2.00	0.0260
Heptachlor	2	2.60	0.76	0.0199
Lasso	5	6.49	1.40	0.0909
Linuron	2	2.60	1.05	0.0273
Malathion	6	7.79	0.01	0.0008
Methoxychlor	2	2.60	0.01	0.0003
Methylmercury dicyandiamide	1	1.30	0.01	0.0001
MSMA	1	1.30	4.00	0.0519
NPA	1	1.30	4.00	0.0519
Ramrod	4	5.19	2.06	0.1071
Trifluralin	1	1.30	1.00	0.0130
Iowa, 152 Sites				
Aldrin	15	9.87	0.83	0.0820
Amiben	14	9.21	0.84	0.0776
Atrazine	24	15.79	1.50	0.2367
Bux-ten (bux)	8	5.26	0.99	0.0520
Captan	2	1.32	0.01	0.0001
Carbaryl	1	0.66	1.60	0.0105
Chevron RE-5353	1	0.66	0.70	0.0046
CIPC	1	0.66	0.66	0.0043
2,4-D	17	11.18	0.60	0.0669
2,4-DB	2	1.32	0.88	0.0115
Diazinon	3	1.97	0.50	0.0099
Fensulfothion	2	1.32	1.38	0.0181
Heptachlor	5	3.29	0.61	0.0199
Lasso	3	1.97	0.91	0.0180
Lindane	1	0.66	0.02	0.0001
Linuron	1	0.66	0.60	0.0039
NPA	1	0.66	1.00	0.0066
Parathion,ethyl	1	0.66	0.02	0.0001
Phorate	7	4.61	0.85	0.0391
Ramrod	11	7.24	1.37	0.0991
Sutan	2	1.32	4.50	0.0592
Trifluralin	3	1.97	0.40	0.0079
Kentucky, 31 Sites				
Amiben	2	6.45	2.00	0.1290
Atrazine	2	6.45	1.75	0.1129
Chloroxuron	1	3.23	2.00	0.0645
2,4-D	2	6.45	0.88	0.0565
Dalapon	1	3.23	1.00	0.0323
Louisiana, 25 Sites				
Aldrin	3	12.00	0.10	0.0124
Azinphosmethyl	3	12.00	1.18	0.1420
Buturon	2	8.00	0.01	0.0008
Captan	1	4.00	0.02	0.0008
Ceresan L	2	8.00	0.01	0.0008
Cotoran	1	4.00	1.00	0.0400
2,4-D	4	16.00	0.88	0.1400
Dalapon	3	12.00	3.67	0.4400
2,4-DB	1	4.00	0.75	0.0300
DDT	2	8.00	2.50	0.2000
DEF	1	4.00	1.12	0.0448
Diuron	1	4.00	0.70	0.0280
DSMA	1	4.00	6.00	0.2400
Norea	1	4.00	1.00	0.0400
NPA	1	4.00	2.00	0.0800
Parathion, methyl	6	24.00	3.54	0.8500
Propanil	2	8.00	3.00	0.2400
Silvex	2	8.00	0.75	0.0600
TCA	2	8.00	5.25	0.4200
TDE	1	4.00	6.00	0.2400
Terbacil	2	8.00	0.39	0.0316
Toxaphene	3	12.00	6.33	0.7600
Trifluralin	4	16.00	0.81	0.1300
Michigan, 34 Sites				
Atrazine	4	11.76	3.38	0.3971
Azinphosmethyl	3	8.82	3.75	0.3309
Captan	2	5.88	13.00	0.7647
Carbaryl	2	5.88	15.00	0.8824
CDEA	1	2.94	2.00	0.0588
Chlordane	1	2.94	1.00	0.0294
2,4-D	3	8.82	1.17	0.1029
Dodine	2	5.88	2.22	0.1309
EPTC	2	5.88	3.50	0.2059
Ethion	1	2.94	2.50	0.0735
Ferbam	1	2.94	4.60	0.1353
Malathion	1	2.94	3.75	0.1102
Simazine	1	2.94	2.00	0.0588
Sulfur	2	5.88	97.50	5.7353

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TABLE 2 (cont'd). *Pesticides applied to cropland by State, FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (lb/a)[1]	Arith. Mean (lb/a)[1]
Mid-Atlantic States,[2] 15 Sites				
Aldrin	1	6.67	1.20	0.0800
Atrazine	2	13.33	1.28	0.1707
Azinphosmethyl	1	6.67	0.05	0.0033
Captan	7	46.67	0.02	0.0107
2,4-D	3	20.00	0.77	0.1533
EPTC	1	6.67	100.00	6.6667
Heptachlor	1	6.67	0.04	0.0027
Lasso	1	6.67	0.20	0.0133
Linuron	1	6.67	0.15	0.0100
Malathion	4	26.67	0.01	0.0027
Maneb	1	6.67	2.00	0.1333
Methoxychlor	2	13.33	0.01	0.0013
Methyl demeton	1	6.67	2.00	0.1333
Phorate	1	6.67	20.00	1.3333
Simazine	1	6.67	2.20	0.1467
Minnesota, 119 Sites				
Amiben	4	3.36	2.00	0.0672
Atrazine	6	5.04	1.90	0.0958
Bux-ten (bux)	1	0.84	4.00	0.0336
Captan	2	1.68	0.01	0.0002
Carbaryl	2	1.68	1.45	0.0244
2,4-D	10	8.40	0.74	0.0626
Dalapon	1	0.84	1.00	0.0084
Isopestox	1	0.84	0.01	0.0001
Lasso	1	0.84	1.00	0.0084
Linuron	1	0.84	2.50	0.0210
Malathion	1	0.84	0.01	0.0001
MCPA	7	5.88	0.86	0.0504
Phorate	2	1.68	10.50	0.1765
Ramrod	7	5.88	1.94	0.1143
Silvex	1	0.84	0.40	0.0034
Mississippi, 31 Sites				
Azinphosmethyl	1	3.23	3.00	0.0968
Bidrin	6	19.35	0.23	0.0452
Captan	1	3.23	0.01	0.0003
Carbaryl	2	6.45	4.50	0.2903
Ceresan red	3	9.68	0.01	0.0010
Chloroneb	2	6.45	0.01	0.0006
Cotoran	8	25.81	0.38	0.0977
DDT	10	32.26	6.22	2.0081
DEF	2	6.45	1.13	0.0726
Dinitrobutylphenol	1	3.23	0.52	0.0168
Dinitrocresol	2	6.45	0.10	0.0068
Disulfoton	3	9.68	0.02	0.0016
Diuron	4	12.90	0.13	0.0171
DSMA	1	3.23	0.62	0.0200
Endrin	1	3.23	1.65	0.0532
EPN	1	3.23	1.70	0.0548
Folex	5	16.13	1.22	0.1968
Lasso	1	3.23	0.35	0.0113
Linuron	2	6.45	0.79	0.0510
Monuron	1	3.23	0.38	0.0123
MSMA	6	19.35	0.71	0.1384
Nitralin	2	6.45	0.88	0.0565
NPA	1	3.23	0.26	0.0084
Paraquat	3	9.68	0.16	0.0152
Parathion, methyl	15	48.39	4.82	2.3342
PCNB	1	3.23	0.01	0.0003
Sodium chlorate	1	3.23	3.00	0.0968
Toxaphene	7	22.58	11.86	2.6774
Trifluralin	13	41.94	0.98	0.4113
Missouri, 81 Sites				
Aldrin	10	12.35	1.00	0.1235
Amiben	5	6.17	1.35	0.0833
Atrazine	17	20.99	1.83	0.3840
Carbaryl	1	1.23	2.00	0.0247
2,4-D	9	11.11	0.58	0.0648
Diazinon	1	1.23	0.60	0.0074
Diuron	3	3.70	0.83	0.0309
Heptachlor	1	1.23	1.00	0.0123
Linuron	2	2.47	0.50	0.0123
Ramrod	3	3.70	1.52	0.0562
Sutan	1	1.23	4.00	0.0494
Trifluralin	5	6.17	0.85	0.0525
Nebraska, 106 Sites				
Aldrin	1	0.94	0.50	0.0047
Amiben	2	1.89	0.63	0.0118
Atrazine	16	15.09	1.28	0.1937

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TABLE 2 (cont'd). *Pesticides applied to cropland by State, FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (lb/a)[1]	Arith. Mean (lb/a)[1]
Bux-ten (bux)	2	1.89	1.22	0.0231
Captan	18	16.98	0.01	0.0017
Carbaryl	1	0.94	1.60	0.0151
Ceresan L	1	0.94	0.10	0.0009
2,4-D	9	8.49	0.60	0.0509
Dalapon	1	0.94	2.50	0.0236
Demeton	1	0.94	0.25	0.0024
Diazinon	1	0.94	0.22	0.0021
Dieldrin	1	0.94	0.01	0.0001
Disulfoton	3	2.83	1.14	0.0324
Endrin	2	1.89	0.22	0.0042
Fensulfothion	2	1.89	1.03	0.0195
Heptachlor	2	1.89	0.01	0.0002
Malathion	18	16.98	0.01	0.0017
Methoxychlor	2	1.89	0.01	0.0002
Methylmercury dicyandiamide	1	0.94	0.01	0.0001
Phorate	6	5.66	0.95	0.0540
Ramrod	4	3.77	1.09	0.0410
Thiram	3	2.83	0.01	0.0003
New England,[4] 18 Sites				
No pesticides applied				
New York, 35 Sites				
Atrazine	5	14.29	2.00	0.2857
Azinphosmethyl	1	2.86	37.50	1.0714
Captan	5	14.29	30.01	4.2869
Carbaryl	3	8.57	8.33	0.7143
2,4-D	4	11.43	0.63	0.0726
Demeton	1	2.86	1.50	0.0429
Dichlorprop	1	2.86	0.50	0.0143
Dicofol	1	2.86	4.04	0.1154
Dieldrin	1	2.86	0.02	0.0006
Dodine	1	2.86	11.25	0.3214
EPTC	1	2.86	3.00	0.0857
Malathion	4	11.43	0.01	0.0011
Methoxychlor	3	8.57	0.01	0.0009
Methylmercury dicyandiamide	2	5.71	<0.01	0.0003
Nitrate	7	20.00	51.71	10.3429
Sutan	1	2.86	3.75	0.1071
Thiram	1	2.86	0.10	0.0029
North Carolina, 31 Sites				
Amiben	1	3.23	2.00	0.0645
Atrazine	8	25.81	2.20	0.5677
Azodrin	1	3.23	0.60	0.0194
Captan	1	3.23	0.01	0.0003
Carbaryl	3	9.68	1.32	0.1274
Ceresan red	2	6.45	0.10	0.0065
Copper oxide	1	3.23	1.80	0.0581
Copper-8-quinolinolate	1	3.23	0.01	0.0003
2,4-D	3	9.68	0.83	0.0806
DDT	4	12.90	1.60	0.2065
Diazinon	2	6.45	3.58	0.2310
Dichloropropane	1	3.23	26.00	0.8387
Dichloropropene	2	6.45	64.21	4.1426
Dinitrobutylphenol	1	3.23	1.50	0.0484
Diphenamid	2	6.45	3.00	0.1935
Endosulfan (I)	1	3.23	0.08	0.0026
Lindane	1	3.23	0.01	0.0003
Malathion	1	3.23	2.50	0.0806
Maleic hydrazide	3	9.68	1.80	0.1742
MSMA	2	6.45	2.38	0.1532
Parathion, ethyl	2	6.45	0.60	0.0387
Sulfur	1	3.23	33.75	1.0887
TDE	4	12.90	1.33	0.1710
Thiram	1	3.23	0.01	0.0003
Toxaphene	1	3.23	2.00	0.0645
Ohio, 69 Sites				
Aldrin	6	8.70	1.67	0.1449
Amiben	8	11.59	1.55	0.1801
Atrazine	12	17.39	1.70	0.2955
Captan	1	1.45	0.01	0.0001
CDAA	1	1.45	0.60	0.0087
2,4-D	9	13.04	0.71	0.0920
Dicamba	1	1.45	0.06	0.0009
Dieldrin	1	1.45	1.00	0.0145
Heptachlor	2	2.90	2.56	0.0743
Malathion	2	2.90	0.50	0.0146
Parathion, ethyl	1	1.45	2.00	0.0290
Ramrod	3	4.35	1.40	0.0609
Vernolate	1	1.45	8.00	0.1159

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TABLE 2 (cont'd). *Pesticides applied to cropland by State, FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (lb/a)[1]	Arith. Mean (lb/a)[1]
Oklahoma, 56 Sites				
Borax	2	3.57	1.25	0.0446
Ceresan M	4	7.14	0.01	0.0007
Ceresan red	3	5.36	0.01	0.0005
2,4-D	2	3.57	0.75	0.0268
Disulfoton	1	1.79	0.50	0.0089
Parathion, ethyl	2	3.57	0.75	0.0268
Parathion, methyl	2	3.57	0.50	0.0179
PCNB	1	1.79	0.01	0.0002
Picloram	1	1.79	1.00	0.0179
Toxaphene	1	1.79	2.00	0.0357
Trifluralin	2	3.57	0.88	0.0313
Pennsylvania, 29 Sites				
Amitrole	1	3.45	2.11	0.0728
Atrazine	4	13.79	2.16	0.2983
Azinphosmethyl	1	3.45	0.25	0.0086
2,4-D	3	10.34	0.10	0.0100
Malathion	2	6.90	1.13	0.0776
Methoxychlor	2	6.90	1.13	0.0776
Parathion, ethyl	1	3.45	0.25	0.0086
Silvex	1	3.45	0.81	0.0279
South Carolina, 9 Sites				
Carbaryl	3	33.33	0.37	0.1222
2,4-D	1	11.11	0.50	0.0556
DDT	1	11.11	2.00	0.2222
Mevinphos	2	22.22	0.10	0.0222
Parathion, ethyl	1	11.11	1.00	0.1111
TDE	1	11.11	3.00	0.3333
Toxaphene	2	22.22	0.80	0.1778
Trifluralin	3	33.33	0.60	0.2000
South Dakota, 106 Sites				
Aldrin	2	1.89	0.25	0.0048
Atrazine	7	6.60	1.00	0.0658
Barban	1	0.94	0.20	0.0019
Bux-ten (bux)	1	0.94	10.00	0.0943
Captan	20	18.87	0.01	0.0020
Ceresan M	2	1.89	0.01	0.0002
2,4-D	26	24.53	0.48	0.1174
Dieldrin	2	1.89	0.01	0.0002
Heptachlor	1	0.94	0.06	0.0006
Lindane	1	0.94	0.01	0.0001
Malathion	15	14.15	0.11	0.0155
Maneb	1	0.94	0.01	0.0001
MCPA	2	1.89	0.17	0.0033
Methoxychlor	2	1.89	0.08	0.0015
Methylmercury dicyandiamide	7	6.60	0.01	0.0007
Thiram	2	1.89	0.01	0.0002
Toxaphene	1	0.94	2.00	0.0189
Tennessee, 23 Sites				
Atrazine	3	13.04	2.00	0.2609
Carbaryl	1	4.35	7.20	0.3130
Ceresan red	2	8.70	0.01	0.0009
Chloroxuron	2	8.70	1.13	0.0978
Cotoran	2	8.70	0.84	0.0730
2,4-D	1	4.35	1.50	0.0652
DAC	1	4.35	5.00	0.2174
Dalapon	1	4.35	4.00	0.1739
2,4-DB	2	8.70	0.19	0.0170
DDT	1	4.35	0.95	0.0413
Disulfoton	1	4.35	0.01	0.0004
EPTC	1	4.35	0.50	0.0217
Linuron	3	13.04	0.51	0.0670
MSMA	1	4.35	0.28	0.0122
Nitralin	1	4.35	0.60	0.0261
NPA	2	8.70	2.43	0.2113
Parathion, methyl	1	4.35	0.47	0.0204
PCNB	1	4.35	0.01	0.0004
Sodium chlorate	1	4.35	4.50	0.1957
Toxaphene	1	4.35	1.90	0.0826
Trifluralin	1	4.35	1.11	0.0483
Virginia and West Virginia, 21 Sites				
Atrazine	3	14.29	1.33	0.1905
Azinphosmethyl	1	4.76	0.50	0.0238
Captan	2	9.52	0.09	0.0086
DDT	1	4.76	0.25	0.0119
Lindane	1	4.76	0.01	0.0005
Malathion	1	4.76	0.01	0.0005
Sutan	1	4.76	3.00	0.1429
Toxaphene	1	4.76	0.50	0.0238

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TABLE 2 (cont'd). *Pesticides applied to cropland by State, FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (lb/a)[1]	Arith. Mean (lb/a)[1]
Wisconsin, 67 Sites				
Aldrin	1	1.49	5.00	0.0746
Amiben	2	2.99	11.50	0.3433
Atrazine	17	25.37	2.12	0.5373
Carbaryl	1	1.49	1.25	0.0187
2,4-D	2	2.99	0.57	0.0172
Diazinon	1	1.49	9.00	0.1343
Disulfoton	1	1.49	1.00	0.0149
MCPA	1	1.49	0.25	0.0037
Phorate	1	1.49	7.00	0.1045
Ramrod	1	1.49	1.50	0.0224
Trifluralin	1	1.49	1.50	0.0224

[1] To convert lb/a to kg/ha., multiply by 1.1208.
[2] Use records were available for only 51 of the 150 sites in Illinois
[3] Mid-Atlantic States include Maryland, Delaware, and New Jersey.
[4] New England States include Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.

TABLE 3. *Pesticides applied to cropland by crop, FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (lb/a)[1]	Arith. Mean (lb/a)[1]
Alfalfa and Bur Clover, 114 Sites				
Azinphosmethyl	2	1.75	0.38	0.0066
Carbaryl	1	0.88	1.00	0.0088
Malathion	2	1.75	1.13	0.0197
Methoxychlor	2	1.75	1.13	0.0197
Parathion, ethyl	3	2.63	0.50	0.0132
Field Corn, 366 Sites				
Aldrin	51	13.93	1.00	0.1398
Amiben	3	0.82	1.47	0.0120
Amitrole	1	0.27	2.11	0.0058
Atrazine	146	39.89	1.75	0.7001
Bux-ten (bux)	16	4.37	2.27	0.0990
Captan	87	23.77	0.02	0.0052
Carbaryl	5	1.37	1.49	0.0204
CDAA	1	0.27	0.60	0.0016
Ceresan red	1	0.27	0.10	0.0003
Chevron RE-5353	1	0.27	0.70	0.0019
2,4-D	72	19.67	0.64	0.1266
Dalapon	2	0.55	2.50	0.0137
2,4-DB	1	0.27	1.00	0.0027
DDT	1	0.27	0.25	0.0007
Diazinon	9	2.46	2.15	0.0528
Dicamba	1	0.27	0.02	0.0001
Dichlorprop	1	0.27	0.50	0.0014
Disulfoton	4	1.09	1.11	0.0121
Fensulfothion	4	1.09	1.20	0.0132
Furadan	1	0.27	1.00	0.0027
Heptachlor	20	5.46	0.79	0.0433
Isopestox	1	0.27	0.01	0.0000
Lasso	3	0.82	0.92	0.0076
Lindane	3	0.82	0.01	0.0001
Linuron	4	1.09	0.90	0.0098
Malathion	71	19.40	0.01	0.0019
Maneb	1	0.27	0.01	0.0000
MCPA	1	0.27	1.00	0.0027
Methoxychlor	18	4.92	0.02	0.0011
MSMA	1	0.27	3.00	0.0082
Nitrate	4	1.09	49.88	0.5451
Parathion, ethyl	1	0.27	0.02	0.0001
Phorate	16	4.37	1.23	0.0539
Ramrod	40	10.93	1.49	0.1628
Silvex	2	0.55	0.45	0.0025
Simazine	1	0.27	2.20	0.0060
Sutan	5	1.37	3.95	0.0540
Thiram	2	0.55	0.01	0.0001
Toxaphene	1	0.27	0.50	0.0014

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TABLE 3 (cont'd). *Pesticides applied to cropland by crop, FY-70*

Pesticide	No. Sites Using Pesticide	Percent Sites Using Pesticide	Arith. Mean Appl. Rate (lb/a)[1]	Arith. Mean (lb/a)[1]
Cotton, 52 Sites				
Azinphosmethyl	1	1.92	3.00	0.0577
Azodrin	6	11.54	4.28	0.4942
Bidrin	8	15.38	0.31	0.0471
Calcium arsenate	1	1.92	9.80	0.1885
Captan	1	1.92	0.01	0.0002
Carbaryl	4	7.69	5.15	0.3962
Ceresan L	1	1.92	0.01	0.0002
Ceresan M	2	3.85	0.05	0.0021
Ceresan red	7	13.46	0.04	0.0048
Chlorobenzilate	1	1.92	1.00	0.0192
Chloroneb	5	9.62	0.01	0.0012
Cotoran	13	25.00	0.64	0.1608
DAC	1	1.92	4.00	0.0769
DDT	24	46.15	4.69	2.1625
DEF	6	11.54	1.44	0.1658
Dicofol	2	3.85	0.88	0.0337
Dimenthoate	1	1.92	0.33	0.0063
Dinitrocresol	2	3.85	0.10	0.0040
Disulfoton	4	7.69	0.01	0.0012
Diuron	8	15.38	0.47	0.0717
DSMA	6	11.54	2.02	0.2331
Endothall	1	1.92	0.90	0.0173
Endrin	3	5.77	4.16	0.2400
EPN	2	3.85	1.10	0.0423
Folex	7	13.46	1.30	0.1750
Linuron	2	3.85	0.79	0.0304
Malathion	1	1.92	2.50	0.0481
Methyl demeton	1	1.92	0.25	0.0048
Methylmercury dicyandiamide	1	1.92	0.01	0.0002
Methyl trithion	2	3.85	7.75	0.2981
Monuron	2	3.85	0.31	0.0121
MSMA	11	21.15	1.48	0.3138
Norea	1	1.92	1.00	0.0192
Nitralin	5	9.62	0.70	0.0669
Paraquat	6	11.54	0.18	0.0210
Parathion, ethyl	2	3.85	0.09	0.0035
Parathion, methyl	31	59.62	4.89	2.9129
PCNB	2	3.85	0.01	0.0004
Phorate	1	1.92	0.50	0.0096
Prometryne	1	1.92	0.75	0.0144
Sodium chlorate	4	7.69	6.88	0.5288
Strobane	1	1.92	3.00	0.0577
TDE	1	1.92	6.00	0.1154
Toxaphene	20	38.46	6.94	2.6696
Trifluralin	23	44.23	1.03	0.4550
Grass/Hay, 30 Sites				
Atrazine	1	3.33	2.50	0.0833
Simazine	1	3.33	2.50	0.0833
Mixed Hay, 119 Sites				
Malathion	1	0.84	1.00	0.0084
Parathion, ethyl	1	0.84	2.00	0.0168
Soybeans, 257 Sites				
Amiben	47	18.29	1.48	0.2710
Azinphosmethyl	1	0.39	4.00	0.0156
Captan	3	1.17	0.03	0.0004
Carbaryl	5	1.95	1.36	0.0265
CDEA	1	0.39	2.00	0.0078
Ceresan red	1	0.39	0.10	0.0004
CIPC	1	0.39	0.66	0.0026
Chloroxuron	3	1.17	1.42	0.0165
Cotoran	1	0.39	0.90	0.0035
DAC	1	0.39	5.00	0.0195
Dalapon	2	0.78	4.50	0.0350
2,4-DB	5	1.95	0.43	0.0083
DDT	3	1.17	16.65	0.1944
Dinitrobutylphenol	3	1.17	4.17	0.0487
Dinitrocyclohexylphenol	1	0.39	0.50	0.0019
EPTC	1	0.39	0.50	0.0019
Lasso	9	3.50	1.10	0.0386
Linuron	9	3.50	0.87	0.0303
Methylmercury dicyandiamide	1	0.39	0.01	0.0000
Nitralin	2	0.78	0.88	0.0068
NPA	6	2.33	2.02	0.0472
Parathion, ethyl	1	0.39	48.00	0.1868
Parathion, methyl	10	3.89	3.05	0.1186
Ramrod	3	1.17	1.33	0.0156
Toxaphene	3	1.17	49.30	0.5755
Trifluralin	22	8.56	0.78	0.0670
Vernolate	2	0.78	4.65	0.0362

[1] To convert lb/a to kg/ha., multiply by 1.1208.

TABLE 4. *Chlorinated hydrocarbon residues in cropland soil, all sites*[1]*—FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Geom. Mean Conc., ppm	95% Conf. Interval about Geom. Mean, ppm	Range of Detected Residues, ppm
Aldrin	203	13.48	0.02	0.0032	0.0027-0.0038	0.01- 4.25
Chlordane	165	10.96	0.08	0.0044	0.0036-0.0053	0.01- 13.34
DAC	1	0.07	<0.01	—	—	1.19
o,p'-DDE	43	2.86	<0.01	—	—	0.01- 0.51
p,p'-DDE	317	21.05	0.05	0.0062	0.0053-0.0071	0.01- 6.82
o,p'-DDT	211	14.01	0.04	0.0037	0.0031-0.0043	0.01- 11.70
p,p'-DDT	305	20.25	0.18	0.0085	0.0072-0.0098	0.01- 69.30
DDTR	343	22.78	0.30	0.0116	0.0099-0.0134	0.01-113.09
Dieldrin	465	30.88	0.04	0.0097	0.0086-0.0109	0.01- 1.85
Endosulfan (I)	1	0.07	<0.01	—	—	0.01
Endosulfan (II)	4	0.27	<0.01	—	—	0.02- 0.07
Endosulfan sulfate	5	0.33	<0.01	—	—	0.10- 0.29
Endrin	27	1.79	<0.01	—	—	0.01- 0.90
Heptachlor	98	6.51	0.01	—	—	0.01- 1.71
Heptachlor epoxide	147	9.76	0.01	0.0016	0.0013-0.0019	0.01- 0.34
Isodrin	34	2.26	<0.01	—	—	0.01- 0.18
Lindane	6	0.40	<0.01	—	—	0.01- 0.15
Nitralin	1	0.07	<0.01	—	—	2.47
Ramrod	1	0.07	<0.01	—	—	0.03
o,p'-TDE	37	2.46	0.01	—	—	0.01- 4.87
p,p'-TDE	217	14.41	0.03	0.0033	0.0028-0.0038	0.01- 20.40
Toxaphene	27	1.79	0.06	—	—	0.79- 8.75
Trifluralin	33	2.19	<0.01	—	—	0.01- 0.36

NOTE: All residues on dry-weight basis.
[1] 1,506 analyses, 35 States.

TABLE 5. *Chlorinated hydrocarbon residues in cropland soil by State, FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Range of Detected Residues, ppm
Alabama, 21 Sites				
Chlordane	1	4.76	0.01	0.23
DAC	1	4.76	0.06	1.19
o,p'-DDE	2	9.52	<0.01	0.02-0.08
p,p'-DDE	17	80.95	0.13	0.02-0.49
o,p'-DDT	13	61.90	0.09	0.01-0.47
p,p'-DDT	16	76.19	0.50	0.03-3.08
DDTR	17	80.95	0.77	0.05-3.83
Dieldrin	4	19.05	<0.01	0.01-0.03
Endrin	2	9.52	0.01	0.05-0.16
Heptachlor epoxide	1	4.76	<0.01	0.03
Lindane	2	9.52	<0.01	0.01
o,p'-TDE	2	9.52	0.01	0.04-0.08
p,p'-TDE	12	57.14	0.04	0.01-0.20
Trifluralin	6	28.57	0.02	0.02-0.13
Arkansas, 47 Sites				
Aldrin	8	17.02	<0.01	0.01-0.05
o,p'-DDE	3	6.38	<0.01	0.01-0.03
p,p'-DDE	25	53.19	0.13	0.01-1.25
o,p'-DDT	15	31.91	0.06	0.01-0.62
p,p'-DDT	22	46.81	0.47	0.03-3.98
DDTR	25	53.19	0.69	0.02-5.30
Dieldrin	12	25.53	0.03	0.04-0.22
Endrin	3	6.38	<0.01	0.01-0.03
Lindane	1	2.13	<0.01	0.01
Nitralin	1	2.13	0.05	2.47
o,p'-TDE	2	4.26	0.01	0.09-0.21
p,p'-TDE	18	38.30	0.03	0.01-0.31
Trifluralin	2	4.26	0.01	0.01-0.36
California, 65 Sites				
Aldrin	1	1.54	<0.01	0.17
Chlordane	2	3.08	<0.01	0.10-0.20
o,p'-DDE	14	21.54	0.01	0.01-0.38
p,p'-DDE	41	63.08	0.17	0.01-1.39
o,p'-DDT	32	49.23	0.08	0.01-0.62
p,p'-DDT	40	61.54	0.38	0.01-5.16
DDTR	46	70.77	0.74	0.01-7.75
Dieldrin	23	35.38	0.05	0.01-1.28
Endosulfan (I)	1	1.54	<0.01	0.01
Endosulfan (II)	2	3.08	<0.01	0.04-0.06
Endosulfan sulfate	2	3.08	0.01	0.17-0.29
Endrin	5	7.69	<0.01	0.02-0.10
Heptachlor expoxide	2	3.08	<0.01	0.01
o,p'-TDE	12	18.46	0.01	0.01-0.26
p,p'-TDE	34	52.31	0.08	0.01-1.20
Toxaphene	13	20.00	0.61	0.79-7.63

(Continued next page)

TABLE 5 (cont'd). *Chlorinated hydrocarbon residues in cropland soil by State, FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Range of Detected Residues, ppm
Florida, 17 Sites				
Aldrin	1	5.88	<0.01	0.06
Chlordane	2	11.76	0.17	0.10- 2.72
p,p'-DDE	7	41.18	0.35	0.01- 5.41
o,p'-DDT	5	29.41	0.25	0.01- 4.18
p,p'-DDT	9	52.94	1.24	0.02-20.26
DDTR	9	52.94	1.97	0.03-31.99
Dieldrin	5	29.41	0.21	0.05- 1.85
Endrin	1	5.88	0.05	0.90
Heptachlor	1	5.88	0.01	0.19
Heptachlor epoxide	1	5.88	0.01	0.09
p,p'-TDE	3	17.65	0.13	0.01- 2.14
Toxaphene	1	5.88	0.34	5.71
Georgia, 28 Sites				
o,p'-DDE	4	14.29	<0.01	0.01-0.02
p,p'-DDE	23	82.14	0.22	0.01-1.09
o,p'-DDT	19	67.86	0.13	0.02-0.84
p,p'-DDT	23	82.14	0.74	0.02-3.38
DDTR	24	85.71	1.21	0.03-5.11
Lindane	1	3.57	<0.01	0.07
o,p'-TDE	2	7.14	<0.01	0.02-0.09
p,p'-TDE	21	75.00	0.11	0.01-0.99
Toxaphene	3	10.71	0.17	1.21-2.27
Trifluralin	2	7.14	<0.01	0.02-0.03
Illinois, 140 Sites				
Aldrin	73	52.14	0.08	0.01-1.38
Chlordane	48	34.29	0.25	0.05-3.76
p,p'-DDE	11	7.86	0.01	0.02-0.16
o,p'-DDT	2	1.43	<0.01	0.01-0.02
p,p'-DDT	13	9.29	0.01	0.02-0.20
DDTR	14	10.00	0.01	0.03-0.33
Dieldrin	96	68.57	0.15	0.02-0.92
Heptachlor	45	32.14	0.03	0.01-0.65
Heptachlor epoxide	46	32.86	0.02	0.01-0.34
Isodrin	20	14.29	<0.01	0.01-0.04
Lindane	1	0.71	<0.01	0.02
p,p'-TDE	5	3.57	<0.01	0.02-0.04
Trifluralin	1	0.71	<0.01	0.03
Indiana, 78 Sites				
Aldrin	15	19.23	0.07	0.01-1.61
Chlordane	6	7.69	0.07	0.09-1.51
Dieldrin	17	21.79	0.04	0.02-0.58
Heptachlor	7	8.97	0.01	0.01-0.21
Heptachlor epoxide	5	6.41	<0.01	0.01-0.12
Isodrin	5	6.41	<0.01	0.01-0.18
Trifluralin	1	1.28	<0.01	0.06
Iowa, 150 Sites				
Aldrin	43	28.67	0.03	0.01-0.68
Chlordane	30	20.00	0.17	0.01-8.04
p,p'-DDE	10	6.67	<0.01	0.01-0.22
o,p'-DDT	6	4.00	<0.01	0.01-0.09
p,p'-DDT	14	9.33	0.01	0.02-0.41
DDTR	14	9.33	0.02	0.03-0.72
Dieldrin	95	63.33	0.07	0.01-0.56
Heptachlor	19	12.67	0.02	0.01-1.71
Heptachlor epoxide	33	22.00	0.01	0.01-0.28
Isodrin	1	0.67	<0.01	0.01
Lindane	1	0.67	<0.01	0.15
Ramrod	1	0.67	<0.01	0.03
p,p'-TDE	8	5.33	<0.01	0.01-0.05
Kentucky, 30 Sites				
Aldrin	1	3.33	<0.01	0.04
o,p'-DDE	1	3.33	<0.01	0.01
p,p'-DDE	8	26.67	0.01	0.01-0.15
o,p'-DDT	3	10.00	0.01	0.02-0.09
p,p'-DDT	6	20.00	0.02	0.02-0.31
DDTR	8	26.67	0.04	0.02-0.59
Dieldrin	8	26.67	0.01	0.01-0.06
o,p'-TDE	1	3.33	<0.01	0.03
p,p'-TDE	6	20.00	0.01	0.01-0.11
Toxaphene	1	3.33	0.03	0.89

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TABLE 5 (cont'd). *Chlorinated hydrocarbon residues in cropland soil by State, FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Range of Detected Residues, ppm
Louisiana, 26 Sites				
Aldrin	1	3.85	<0.01	0.04
o,p'-DDE	2	7.69	<0.01	0.02-0.10
p,p'-DDE	12	46.15	0.20	0.02-1.98
o,p'-DDT	10	38.46	0.07	0.01-0.56
p,p'-DDT	12	46.15	0.40	0.06-3.21
DDTR	12	46.15	0.70	0.09-6.02
Dieldrin	8	30.77	0.02	0.02-0.08
Endrin	2	7.69	<0.01	0.02-0.03
Heptachlor	1	3.85	<0.01	0.01
p,p'-TDE	11	42.31	0.03	0.01-0.17
Toxaphene	1	3.85	0.20	5.32
Trifluralin	2	7.69	0.01	0.07-0.19
Michigan, 54 Sites				
Chlordane	3	5.56	0.01	0.07- 0.51
o,p'-DDE	1	1.85	0.01	0.51
p,p'-DDE	7	12.96	0.06	0.01- 2.38
o,p'-DDT	5	9.26	0.16	0.04- 8.21
p,p'-DDT	6	11.11	0.26	0.03-12.03
DDTR	7	12.96	0.53	0.01-25.59
Dieldrin	7	12.96	0.01	0.01- 0.22
Endosulfan (II)	1	1.85	<0.01	0.02
Endosulfan sulfate	1	1.85	<0.01	0.10
Heptachlor	1	1.85	<0.01	0.04
Heptachlor epoxide	2	3.70	<0.01	0.01
o,p'-TDE	1	1.85	0.02	1.30
p,p'-TDE	5	9.26	0.03	0.02- 1.16
Mid-Atlantic States,[1] 19 Sites				
Aldrin	1	5.26	0.01	0.24
Chlordane	4	21.05	0.72	0.11-13.34
p,p'-DDE	3	15.79	0.02	0.01- 0.22
o,p'-DDT	2	10.53	<0.01	0.02- 0.03
p,p'-DDT	5	26.32	0.03	0.01- 0.38
DDTR	5	26.32	0.10	0.01- 1.46
Dieldrin	9	47.37	0.08	0.01- 0.74
Heptachlor epoxide	1	5.26	<0.01	0.03
p,p'-TDE	3	15.79	0.05	0.02- 0.86
Minnesota, 120 Sites				
Aldrin	6	5.00	0.05	0.03-4.25
Chlordane	8	6.67	0.02	0.03-0.94
o,p'-DDE	1	0.83	<0.01	0.01
p,p'-DDE	12	10.00	0.01	0.01-0.25
o,p'-DDT	9	7.50	<0.01	0.01-0.25
p,p'-DDT	13	10.83	0.02	0.02-0.74
DDTR	13	10.83	0.03	0.02-1.29
Dieldrin	17	14.17	0.02	0.01-0.92
Endrin	2	1.67	<0.01	0.01-0.02
Heptachlor	3	2.50	<0.01	0.01-0.05
Heptachlor epoxide	5	4.17	<0.01	0.01-0.09
Isodrin	2	1.67	<0.01	0.01-0.05
p,p'-TDE	4	3.33	<0.01	0.01-0.08
Mississippi, 29 Sites				
Chlordane	1	3.45	<0.01	0.08
o,p'-DDE	8	27.59	0.01	0.02-0.05
p,p'-DDE	27	93.10	0.28	0.01-1.71
o,p'-DDT	22	75.86	0.19	0.02-0.74
p,p'-DDT	27	93.10	1.29	0.01-6.61
DDTR	27	93.10	1.85	0.03-9.81
Dieldrin	6	20.69	0.02	0.01-0.18
Endrin	3	10.34	0.01	0.02-0.11
Heptachlor epoxide	1	3.45	<0.01	0.03
p,p'-TDE	18	62.07	0.08	0.01-0.71
Toxaphene	5	17.24	0.73	2.79-8.75
Trifluralin	5	17.24	0.03	0.03-0.27
Missouri, 81 Sites				
Aldrin	20	24.69	0.04	0.01-0.49
Chlordane	9	11.11	0.16	0.07-5.62
p,p'-DDE	6	7.41	<0.01	0.01-0.10
o,p'-DDT	2	2.47	<0.01	0.03-0.04
p,p'-DDT	6	7.41	0.01	0.03-0.26
DDTR	6	7.41	0.01	0.04-0.43
Dieldrin	28	34.57	0.06	0.01-0.53
Endrin	1	1.23	<0.01	0.02
Heptachlor	8	9.88	0.03	0.02-0.94
Heptachlor Epoxide	8	9.88	0.01	0.01-0.36
Isodrin	1	1.23	<0.01	0.01
p,p'-TDE	3	3.70	<0.01	0.02-0.05
Trifluralin	5	6.17	<0.01	0.02-0.09

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TABLE 5 (cont'd). *Chlorinated hydrocarbon residues in cropland soil by State, FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Range of Detected Residues, ppm
Nebraska, 106 Sites				
Aldrin	4	3.77	<0.01	0.01
Chlordane	16	15.09	0.01	0.02-0.14
o,p'-DDE	1	0.94	<0.01	0.01
p,p'-DDE	10	9.43	<0.01	0.01-0.19
o,p'-DDT	5	4.72	<0.01	0.01-0.06
p,p'-DDT	7	6.60	0.01	0.03-0.28
DDTR	10	9.43	0.01	0.01-0.59
Dieldrin	48	45.28	0.03	0.01-0.17
Endrin	4	3.77	<0.01	0.01-0.03
Heptachlor epoxide	18	16.98	<0.01	0.01-0.02
p,p'-TDE	3	2.83	<0.01	0.01-0.05
New England States,[a] 20 Sites				
Chlordane	1	5.00	0.01	0.19
o,p'-DDE	1	5.00	<0.01	0.03
p,p'-DDE	5	25.00	0.07	0.01-0.68
o,p'-DDT	5	25.00	0.07	0.01-0.86
p,p'-DDT	5	25.00	0.45	0.02-4.65
DDTR	5	25.00	0.65	0.04-6.65
Dieldrin	2	10.00	0.03	0.32-0.33
Endosulfan (II)	1	5.00	<0.01	0.07
Endosulfan sulfate	1	5.00	0.01	0.23
p,p'-TDE	4	20.00	0.05	0.14-0.43
New York, 38 Sites				
Chlordane	1	2.63	0.01	0.28
p,p'-DDE	13	34.21	0.21	0.01- 6.82
o,p'-DDT	6	15.79	0.31	0.01- 11.70
p,p'-DDT	12	31.58	1.87	0.01- 69.30
DDTR	15	39.47	3.06	0.01-113.09
Dieldrin	10	26.32	0.01	0.01- 0.10
Heptachlor epoxide	1	2.63	<0.01	0.06
o,p'-TDE	1	2.63	0.13	4.87
p,p'-TDE	6	15.79	0.54	0.01- 20.40
North Carolina, 30 Sites				
Aldrin	1	3.33	<0.01	0.02
Chlordane	3	10.00	0.01	0.03-0.32
o,p'-DDE	1	3.33	<0.01	0.02
p,p'-DDE	21	70.00	0.07	0.01-0.44
o,p'-DDT	16	53.33	0.06	0.02-0.43
p,p'-DDT	20	66.67	0.31	0.02-2.93
DDTR	22	73.33	0.53	0.03-4.12
Dieldrin	10	33.33	0.03	0.01-0.29
Endrin	2	6.67	<0.01	0.01-0.03
Heptachlor epoxide	1	3.33	<0.01	0.01
o,p'-TDE	8	26.67	0.01	0.01-0.12
p,p'-TDE	18	60.00	0.07	0.01-0.42
Trifluralin	1	3.33	<0.01	0.07
Ohio, 69 Sites				
Aldrin	17	24.64	0.04	0.01-1.84
Chlordane	15	21.74	0.08	0.05-1.44
p,p'-DDE	6	8.70	<0.01	0.01-0.10
o,p'-DDT	1	1.45	<0.01	0.09
p,p'-DDT	3	4.35	<0.01	0.01-0.28
DDTR	7	10.14	0.02	0.02-0.43
Dieldrin	26	37.68	0.05	0.01-0.77
Endrin	1	1.45	<0.01	0.02
Heptachlor	6	8.70	0.01	0.01-0.27
Heptachlor epoxide	9	13.04	<0.01	0.01-0.05
Isodrin	2	2.90	<0.01	0.01-0.09
o,p'-TDE	4	5.80	<0.01	0.02-0.09
p,p'-TDE	6	8.70	0.01	0.01-0.23
Trifluralin	2	2.90	<0.01	0.04-0.06
Oklahoma, 65 Sites				
p,p'-DDE	12	18.46	0.03	0.01-0.89
o,p'-DDT	7	10.77	0.01	0.02-0.20
p,p'-DDT	9	13.85	0.03	0.02-0.57
DDTR	12	18.46	0.07	0.01-1.71
Dieldrin	1	1.54	<0.01	0.07
Endrin	1	1.54	<0.01	0.06
p,p'-TDE	6	9.23	<0.01	0.01-0.08
Toxaphene	1	1.54	0.02	1.60

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TABLE 5 (cont'd). *Chlorinated hydrocarbon residues in cropland soil by State, FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Range of Detected Residues, ppm
Pennsylvania, 32 Sites				
Chlordane	1	3.13	<0.01	0.02
o,p'-DDE	1	3.13	<0.01	0.01
p,p'-DDE	9	28.13	0.05	0.01-0.74
o,p'-DDT	4	12.50	0.01	0.01-0.08
p,p'-DDT	9	28.13	0.04	0.02-0.42
DDTR	9	28.13	0.09	0.04-1.26
Dieldrin	2	6.25	0.01	0.02-0.25
Heptachlor epoxide	2	6.25	<0.01	0.01
p,p'-TDE	4	12.50	<0.01	0.01-0.05
South Carolina, 17 Sites				
Aldrin	1	5.88	<0.01	0.01
Chlordane	1	5.88	0.05	0.92
o,p'-DDE	2	11.76	<0.01	0.02
p,p'-DDE	13	76.47	0.23	0.04-0.77
o,p'-DDT	12	70.59	0.15	0.01-0.59
p,p'-DDT	13	76.47	0.63	0.05-2.98
DDTR	13	76.47	1.10	0.12-4.04
Dieldrin	3	17.65	0.06	0.01-0.98
Endosulfan sulfate	1	5.88	0.01	0.10
o,p'-TDE	1	5.88	0.01	0.09
p,p'-TDE	11	64.71	0.07	0.02-0.61
Toxaphene	2	11.76	0.34	2.44-3.34
Trifluralin	3	17.65	0.01	0.02-0.11
South Dakota, 106 Sites				
Aldrin	6	5.66	0.01	0.01-0.22
Chlordane	1	0.94	<0.01	0.03
p,p'-DDE	1	0.94	<0.01	0.02
o,p'-DDT	2	1.89	<0.01	0.01-0.02
p,p'-DDT	3	2.83	<0.01	0.03-0.04
DDTR	3	2.83	<0.01	0.05
Dieldrin	12	11.32	0.01	0.01-0.46
Isodrin	1	0.94	<0.01	0.01
Tennessee, 25 Sites				
Chlordane	3	12.00	0.05	0.09-0.77
o,p'-DDE	1	4.00	<0.01	0.02
p,p'-DDE	7	28.00	0.02	0.01-0.31
o,p'-DDT	4	16.00	0.01	0.01-0.14
p,p'-DDT	5	20.00	0.04	0.01-0.65
DDTR	8	32.00	0.08	0.01-1.44
Dieldrin	6	24.00	0.01	0.01-0.06
Heptachlor	2	8.00	<0.01	0.01
Heptachlor epoxide	2	8.00	<0.01	0.01-0.11
o,p'-TDE	1	4.00	<0.01	0.08
p,p'-TDE	4	16.00	0.01	0.02-0.24
Trifluralin	1	4.00	<0.01	0.01
Virginia and West Virginia, 26 Sites				
Chlordane	3	11.54	0.02	0.04-0.37
p,p'-DDE	4	15.38	0.01	0.04-0.08
o,p'-DDT	2	7.69	<0.01	0.01-0.03
p,p'-DDT	3	11.54	0.01	0.01-0.14
DDTR	5	19.23	0.02	0.01-0.23
Dieldrin	3	11.54	<0.01	0.02
Heptachlor epoxide	3	11.54	0.01	0.03-0.13
o,p'-TDE	1	3.85	<0.01	0.01
p,p'-TDE	3	11.54	<0.01	0.01-0.06
Wisconsin, 67 Sites				
Aldrin	4	5.97	0.04	0.02-1.40
Chlordane	6	8.96	0.05	0.06-1.46
p,p'-DDE	7	10.45	0.01	0.01-0.34
o,p'-DDT	2	2.99	0.01	0.13-0.35
p,p'-DDT	4	5.97	0.02	0.02-1.11
DDTR	7	10.45	0.04	0.01-1.91
Dieldrin	7	10.45	0.02	0.01-0.34
Heptachlor	5	7.46	<0.01	0.01-0.03
Heptachlor epoxide	6	8.96	<0.01	0.01-0.06
Isodrin	2	2.99	<0.01	0.02-0.03
o,p'-TDE	1	1.49	<0.01	0.01
p,p'-TDE	1	1.49	<0.01	0.10
Trifluralin	2	2.99	<0.01	0.01-0.05

NOTE: All residues on dry-weight basis.
[1] Mid-Atlantic States include Maryland, Delaware, and New Jersey.
[2] New England States include Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.

TABLE 6. *Chlorinated hydrocarbon residues in cropland soil by State, FY-70*
(50% estimate and 95% confidence interval of median)

Pesticide	Upper Limit,[1] ppm	Residue Level, ppm	Lower Limit, ppm
ALABAMA			
p,p'-DDE	0.07	0.06	0.05
o,p'-DDT	0.03	0.02	0.01
p,p'-DDT	0.13	0.11	0.09
DDTR	0.28	0.24	0.20
p,p'-TDE	0.02	0.02	0.01
ARKANSAS			
p,p'-DDE	0.01	0.01	0.01
p,p'-DDT	0.03	0.02	0.01
DDTR	0.04	0.03	0.03
Dieldrin	0.02	0.01	0.01
p,p'-TDE	0.01	0.01	0.00
CALIFORNIA			
p,p'-DDE	0.05	0.04	0.03
o,p'-DDT	0.02	0.02	0.01
p,p'-DDT	0.07	0.06	0.05
DDTR	0.16	0.13	0.11
Dieldrin	0.01	0.00	0.00
p,p'-TDE	0.02	0.02	0.01
Toxaphene	0.34	0.20	0.08
FLORIDA			
p,p'-DDE	0.01	0.00	0.00
p,p'-DDT	0.02	0.01	0.01
DDTR	0.03	0.02	0.01
GEORGIA			
p,p'-DDE	0.11	0.09	0.07
o,p'-DDT	0.05	0.04	0.04
p,p'-DDT	0.37	0.29	0.21
DDTR	0.62	0.46	0.32
p,p'-TDE	0.03	0.03	0.02
ILLINOIS			
Aldrin	0.01	0.01	0.01
Chlordane	0.04	0.03	0.02
p,p'-DDT	0.01	0.00	0.00
Dieldrin	0.07	0.06	0.06
INDIANA			
Chlordane	0.01	0.00	0.00
Dieldrin	0.01	0.00	0.00
IOWA			
Dieldrin	0.02	0.02	0.02
KENTUCKY			
DDTR	0.01	0.00	0.00
LOUISIANA			
p,p'-DDE	0.01	0.01	0.00
o,p'-DDT	0.01	0.00	0.00
p,p'-DDT	0.05	0.03	0.01
DDTR	0.08	0.04	0.02
p,p'-TDE	0.01	0.01	0.00
MISSISSIPPI			
p,p'-DDE	0.12	0.10	0.08
o,p'-DDT	0.10	0.08	0.07
p,p'-DDT	0.53	0.37	0.25
DDTR	0.80	0.57	0.38
p,p'-TDE	0.04	0.03	0.01
MISSOURI			
p,p'-DDT	0.01	0.00	0.00
Dieldrin	0.01	0.01	0.00
NEBRASKA			
Chlordane	0.01	0.00	0.00
p,p'-DDT	0.01	0.00	0.00
Dieldrin	0.01	0.01	0.00
NORTH CAROLINA			
p,p'-DDE	0.03	0.02	0.02
o,p'-DDT	0.02	0.01	0.01
p,p'-DDT	0.06	0.05	0.04
DDTR	0.14	0.12	0.09
Dieldrin	0.01	0.00	0.00
o,p'-TDE	0.01	0.00	0.00
p,p'-TDE	0.03	0.02	0.02
OHIO			
Chlordane	0.01	0.00	0.00
PENNSYLVANIA			
p,p'-DDT	0.01	0.00	0.00
DDTR	0.02	0.01	0.01
SOUTH CAROLINA			
p,p'-DDE	0.15	0.11	0.07
o,p'-DDT	0.06	0.04	0.02
p,p'-DDT	0.24	0.17	0.10
DDTR	0.60	0.40	0.20
p,p'-TDE	0.03	0.02	0.02
WISCONSIN			
Chlordane	0.01	0.00	0.00

NOTE: All residues on dry-weight basis.
[1] Values not shown where upper limit is less than 0.01 ppm.

TABLE 7. *Chlorinated hydrocarbon residues in cropland soil by cropping region, FY-70*
(% sites showing detectable residues)

Pesticide	Corn	Cotton	Cotton & Gen. Farming	Gen. Farming	Hay & Gen. Farming	Irrigated Land	Small Grains	Veg.	Veg. & Fruit
	NUMBER OF SITES ANALYZED								
	713	101	117	147	184	39	105	72	42
	PERCENT OF SITES SHOWING DETECTABLE RESIDUES								
Aldrin	25.39	7.92	2.56	2.04	1.09	5.13	0.95	1.39	4.76
Chlordane	18.51	ND	3.42	6.12	4.35	7.69	0.95	6.94	9.52
DAC	ND	ND	0.85	ND	ND	ND	ND	ND	ND
o,p'-DDE	0.14	12.87	5.98	4.08	2.17	28.21	ND	ND	4.76
p,p'-DDE	6.87	58.42	48.72	41.50	15.22	56.41	2.86	27.78	47.62
o,p'-DDT	3.09	41.58	33.33	30.61	7.07	46.15	1.90	20.83	33.33
p,p'-DDT	7.57	55.45	44.44	37.41	12.50	48.72	1.90	30.56	52.38
DDTR	8.42	59.41	48.72	44.22	15.22	58.97	2.86	33.33	59.52
Dieldrin	45.44	23.76	14.53	17.69	9.78	56.41	4.76	23.61	30.95
Endosulfan I	ND	ND	ND	ND	ND	ND	ND	ND	2.38
Endosulfan II	ND	ND	ND	ND	1.09	2.56	ND	ND	2.38
Endosulfan sulfate	ND	ND	0.85	ND	1.63	2.56	ND	ND	2.38
Endrin	0.42	5.94	4.27	1.36	ND	10.26	3.81	1.39	4.76
Heptachlor	12.76	ND	0.85	0.68	1.63	2.56	ND	ND	2.38
Heptachlor epoxide	17.11	ND	1.71	4.08	4.35	12.82	0.95	1.39	4.76
Isodrin	4.63	ND	ND	ND	0.54	ND	ND	ND	ND
Lindane	0.28	0.99	1.71	0.68	ND	ND	ND	ND	ND
Nitralin	ND	0.99	ND	ND	ND	ND	ND	ND	ND
Ramrod	0.14	ND	ND	ND	ND	ND	ND	ND	ND
o,p'-TDE	0.56	2.97	1.71	9.52	1.09	25.64	ND	1.39	2.38
p,p'-TDE	3.79	41.58	32.48	36.05	5.98	41.03	0.95	18.06	35.71
Toxaphene	ND	8.91	3.42	3.40	ND	20.51	ND	ND	2.38
Trifluralin	0.70	13.86	5.13	4.08	1.09	ND	ND	ND	ND

NOTE: ND = not detected.

TABLE 8. *Chlorinated hydrocarbon residues in cropland soil by cropping region, FY-70*
(Arithmetic mean conc.)

Pesticide	Corn	Cotton	Cotton & Gen. Farming	Gen. Farming	Hay & Gen. Farming	Irrigated Land	Small Grains	Veg.	Veg. & Fruit
	NUMBER OF SITES ANALYZED								
	713	101	117	147	184	39	105	72	42
	ARITHMETIC MEAN CONC., ppm								
Aldrin	0.05	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Chlordane	0.13	ND	0.01	0.02	0.02	0.01	<0.01	0.19	0.07
DAC	ND	ND	0.01	ND	ND	ND	ND	ND	ND
o,p'-DDE	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	ND	ND	0.01
p,p'-DDE	<0.01	0.13	0.15	0.06	0.03	0.16	<0.01	0.13	0.21
o,p'-DDT	<0.01	0.08	0.06	0.05	0.05	0.07	<0.01	0.18	0.13
p,p'-DDT	0.01	0.52	0.35	0.25	0.11	0.31	<0.01	1.06	0.69
DDTR	0.01	0.78	0.59	0.40	0.22	0.64	0.01	1.74	1.11
Dieldrin	0.07	0.04	0.02	0.01	0.01	0.05	<0.01	0.02	0.10
Endosulfan I	ND	ND	ND	ND	ND	ND	ND	ND	<0.01
Endosulfan II	ND	ND	ND	ND	<0.01	<0.01	ND	ND	<0.01
Endosulfan sulfate	ND	ND	<0.01	ND	<0.01	<0.01	ND	ND	0.01
Endrin	<0.01	<0.01	<0.01	<0.01	ND	0.01	<0.01	<0.01	0.02
Heptachlor	0.01	ND	<0.01	<0.01	<0.01	<0.01	ND	ND	<0.01
Heptachlor epoxide	0.01	ND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Isodrin	<0.01	ND	ND	ND	<0.01	ND	ND	ND	ND
Lindane	<0.01	<0.01	<0.01	<0.01	ND	ND	ND	ND	ND
Nitralin	ND	0.02	ND	ND	ND	ND	ND	ND	ND
Ramrod	<0.01	ND	ND	ND	ND	ND	ND	ND	ND
o,p'-TDE	<0.01	<0.01	<0.01	0.01	0.01	0.02	ND	0.07	<0.01
p,p'-TDE	<0.01	0.04	0.03	0.04	0.01	0.07	<0.01	0.30	0.08
Toxaphene	ND	0.32	0.09	0.07	ND	0.68	ND	ND	0.14
Trifluralin	<0.01	0.02	<0.01	<0.01	<0.01	ND	ND	ND	ND

NOTE: ND = not detected.

TABLE 9. *Chlorinated hydrocarbon residues in cropland soil by cropping region, FY-70*
(50% estimate and 95% confidence interval for selected pesticides, ppm)

Pesticide	Parameter	Corn	Cotton	Cotton & Gen. Farming	Gen. Farming	Hay & Gen. Farming	Irrigated Land	Veg.	Veg. & Fruit
Chlordane	Upper Limit	0.002	NC	NC	0.001	0.000	NC	NC	NC
	Residue Level	0.001	NC	NC	0.000	0.000	NC	NC	NC
	Lower Limit	0.001	NC	NC	0.000	0.000	NC	NC	NC
p,p'-DDE	Upper Limit	0.000	0.018	0.010	0.009	0.000	0.039	0.002	0.013
	Residue Level	0.000	0.016	0.008	0.007	0.000	0.024	0.001	0.009
	Lower Limit	0.000	0.013	0.006	0.005	0.000	0.011	0.000	0.005
o,p'-DDT	Upper Limit	NC	0.010	0.006	0.005	0.000	0.038	0.000	0.002
	Residue Level	NC	0.008	0.003	0.004	0.000	0.029	0.000	0.002
	Lower Limit	NC	0.005	0.002	0.003	0.000	0.018	0.000	0.001
p,p'-DDT	Upper Limit	0.000	0.054	0.013	0.013	0.000	0.077	0.001	0.019
	Residue Level	0.000	0.046	0.010	0.009	0.000	0.054	0.001	0.015
	Lower Limit	0.000	0.038	0.007	0.006	0.000	0.033	0.000	0.011
DDTR	Upper Limit	0.000	0.085	0.023	0.022	0.000	0.079	0.002	0.047
	Residue Level	0.000	0.071	0.017	0.016	0.000	0.040	0.002	0.037
	Lower Limit	0.000	0.058	0.012	0.011	0.000	0.014	0.001	0.028
Dieldrin	Upper Limit	0.011	0.003	0.002	0.002	0.000	0.027	0.001	0.003
	Residue Level	0.009	0.002	0.001	0.001	0.000	0.018	0.000	0.002
	Lower Limit	0.007	0.001	0.000	0.000	0.000	0.008	0.000	0.001
p,p'-TDE	Upper Limit	0.000	0.009	0.004	0.008	0.000	0.017	0.000	0.006
	Residue Level	0.000	0.008	0.003	0.006	0.000	0.014	0.000	0.005
	Lower Limit	0.000	0.006	0.002	0.005	0.000	0.010	0.000	0.003
Toxaphene	Upper Limit	NC	0.149	NC	NC	NC	0.336	NC	NC
	Residue Level	NC	0.036	NC	NC	NC	0.171	NC	NC
	Lower Limit	NC	0.001	NC	NC	NC	0.041	NC	NC

NOTE: NC = not calculated, less than 6 different values.
All residues on dry-weight basis.

TABLE 10. *Chlorinated hydrocarbon residues in cropland soil by crop, FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Range of Detected Residues, ppm
Alfalfa and Bur Clover, 114 Sites				
Aldrin	8	7.02	0.01	0.01-0.38
Chlordane	10	8.77	0.04	0.03-1.46
o,p'-DDE	4	3.51	<0.01	0.01-0.03
p,p'-DDE	13	11.40	0.02	0.01-0.74
o,p'-DDT	10	8.77	0.01	0.02-0.14
p,p'-DDT	17	14.91	0.02	0.01-0.42
DDTR	17	14.91	0.06	0.02-1.26
Dieldrin	28	24.56	0.03	0.01-0.51
Endrin	3	2.63	<0.01	0.03-0.07
Heptachlor	4	3.51	<0.01	0.01-0.12
Heptachlor epoxide	9	7.89	<0.01	0.01-0.07
o,p'-TDE	4	3.51	<0.01	0.01-0.08
p,p'-TDE	12	10.53	<0.01	0.01-0.10
Toxaphene	4	3.51	0.08	0.79-4.35
Trifluralin	1	0.88	<0.01	0.02
Field Corn, 363 Sites				
Aldrin	75	20.66	0.06	0.01-4.25
Chlordane	64	17.63	0.15	0.02-8.04
o,p'-DDE	3	0.83	<0.01	0.01-0.02
p,p'-DDE	66	18.18	0.02	0.01-1.09
o,p'-DDT	34	9.37	0.01	0.01-0.84
p,p'-DDT	63	17.36	0.04	0.01-2.98
DDTR	73	20.11	0.07	0.01-4.94
Dieldrin	152	41.87	0.06	0.01-0.92
Endrin	4	1.10	<0.01	0.01-0.03
Heptachlor	40	11.02	0.02	0.01-1.71
Heptachlor epoxide	62	17.08	0.01	0.01-0.31
Isodrin	11	3.03	<0.01	0.01-0.18
Lindane	2	0.55	<0.01	0.07-0.15
Ramrod	1	0.28	<0.01	0.03
o,p'-TDE	6	1.65	<0.01	0.02-0.09
p,p'-TDE	40	11.02	0.01	0.01-0.99
Toxaphene	1	0.28	0.01	2.27
Trifluralin	2	0.55	<0.01	0.04-0.10

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TABLE 10 (cont'd). *Chlorinated hydrocarbon residues in cropland soil by crop, FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Range of Detected Residues, ppm
Cotton, 49 Sites				
Chlordane	1	2.04	<0.01	0.23
DAC	1	2.04	0.02	1.19
o,p'-DDE	15	30.61	0.01	0.02-0.10
p,p'-DDE	40	81.63	0.38	0.01-1.98
o,p'-DDT	37	75.51	0.22	0.01-0.74
p,p'-DDT	38	77.55	1.37	0.04-6.61
DDTR	40	81.63	2.07	0.01-9.81
Dieldrin	9	18.37	0.02	0.01-0.18
Endrin	7	14.29	0.01	0.01-0.16
Heptachlor epoxide	1	2.04	<0.01	0.03
Lindane	2	4.08	<0.01	0.01
Nitralin	1	2.04	0.05	2.47
o,p'-TDE	7	14.29	0.01	0.02-0.12
p,p'-TDE	32	65.31	0.08	0.01-0.71
Toxaphene	7	14.29	0.55	1.04-7.63
Trifluralin	11	22.45	0.02	0.02-0.24
Grass and Hay, 29 Sites				
Aldrin	1	3.45	<0.01	0.04
Chlordane	1	3.45	0.01	0.27
p,p'-DDE	6	20.69	0.01	0.01-0.21
o,p'-DDT	2	6.90	0.01	0.07-0.09
p,p'-DDT	4	13.79	0.02	0.01-0.31
DDTR	6	20.69	0.04	0.02-0.59
Dieldrin	4	13.79	<0.01	0.01-0.06
Heptachlor	1	3.45	<0.01	0.05
Heptachlor epoxide	1	3.45	<0.01	0.09
p,p'-TDE	4	13.79	<0.01	0.01-0.04
Toxaphene	1	3.45	0.03	0.89
Mixed Hay, 118 Sites				
Aldrin	4	3.39	<0.01	0.01-0.04
Chlordane	7	5.93	0.02	0.02-1.23
o,p'-DDE	2	1.69	<0.01	0.01-0.02
p,p'-DDE	13	11.02	0.01	0.01-0.34
o,p'-DDT	7	5.93	<0.01	0.01-0.25
p,p'-DDT	11	9.32	0.02	0.01-1.35
DDTR	14	11.86	0.04	0.01-2.08
Dieldrin	16	13.56	0.01	0.01-0.37
Heptachlor	2	1.69	<0.01	0.09-0.44
Heptachlor epoxide	5	4.24	<0.01	0.01-0.16
o,p'-TDE	3	2.54	<0.01	0.01-0.08
p,p'-TDE	6	5.08	0.01	0.02-0.24
Soybeans, 254 Sites				
Aldrin	37	14.57	0.01	0.01-1.22
Chlordane	19	7.48	0.04	0.01-1.44
o,p'-DDE	7	2.76	<0.01	0.01-0.03
p,p'-DDE	58	22.83	0.03	0.01-1.25
o,p'-DDT	37	14.57	0.02	0.01-0.51
p,p'-DDT	56	22.05	0.11	0.01-3.43
DDTR	59	23.23	0.17	0.01-3.83
Dieldrin	79	31.10	0.03	0.01-0.56
Endrin	2	0.79	<0.01	0.01-0.03
Heptachlor	14	5.51	<0.01	0.01-0.27
Heptachlor epoxide	17	6.69	<0.01	0.01-0.10
Isodrin	2	0.79	<0.01	0.01
Lindane	1	0.39	<0.01	0.02
Nitralin	1	0.39	0.01	2.47
o,p'-TDE	4	1.57	<0.01	0.02-0.21
p,p'-TDE	40	15.75	0.01	0.01-0.31
Toxaphene	3	1.18	0.07	2.79-8.75
Trifluralin	15	5.91	0.01	0.01-0.36

NOTE: All residues on dry-weight basis.

TABLE 11. *Chlorinated hydrocarbon and organophosphate residues in crops, all sites, FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Range of Detected Residues, ppm
Alfalfa and/or Bur Clover				
Chlorinated Hydrocarbons, 39 Sites				
Chlordane	3	7.69	0.01	0.03-0.19
p,p'-DDE	3	7.69	<0.01	0.01-0.02
o,p'-DDT	5	12.82	<0.01	0.01-0.08
p,p'-DDT	11	28.21	0.01	0.01-0.18
DDTR	11	28.21	0.02	0.01-0.34
Dieldrin	3	7.69	<0.01	0.01-0.02
p,p'-TDE	3	7.69	<0.01	0.01-0.14
Organophosphates, 37 Sites: 0 Detections				
Field Corn: Kernels				
Chlorinated Hydrocarbons, 276 Sites				
Dieldrin	1	0.36	<0.01	0.01
Endrin	1	0.36	<0.01	0.03
Organophosphates, 240 Sites				
Ethion	1	0.42	[illegible]01	0.13
Cotton: Stalks and Green Bolls				
Chlorinated Hydrocarbons, 33 Sites				
o,p'-DDE	3	9.09	<0.01	0.02- 0.04
p,p'-DDE	29	87.88	0.31	0.01- 4.37
o,p'-DDT	29	87.88	0.37	0.01- 2.36
p,p'-DDT	29	87.88	2.95	0.03-27.03
DDTR	30	90.91	3.81	0.02-34.63
Dieldrin	7	21.21	<0.01	0.01- 0.05
Endrin	1	3.03	<0.01	0.05
p,p'-TDE	25	75.76	0.17	0.01- 0.87
Toxaphene	15	45.45	6.96	0.68-55.80
Organophosphates, 18 Sites				
DEF	7	38.89	1.54	0.04-14.28
Diazinon	1	5.56	<0.01	0.06
Folex	1	5.56	0.09	1.55
Malathion	4	22.22	0.16	0.08- 2.17
Parathion, ethyl	3	16.67	0.01	0.02- 0.07
Parathion, methyl	9	50.00	0.58	0.13- 6.20
Grass Hay				
Chlorinated Hydrocarbons, 48 Sites				
Chlordane	1	2.08	<0.01	0.16
p,p'-DDE	5	10.42	<0.01	0.01-0.07
o,p'-DDT	3	6.25	0.01	0.05-0.19
p,p'-DDT	5	10.42	0.06	0.02-2.31
DDTR	5	10.42	0.07	0.03-2.60
Dieldrin	1	2.08	<0.01	0.02
p,p'-TDE	1	2.08	<0.01	0.03
Toxaphene	1	2.08	<0.01	0.05
Organophosphates, 47 Sites				
DEF	1	2.13	<0.01	0.01
Disulfoton	3	6.38	<0.01	0.01
Malathion	1	2.13	<0.01	0.03
Parathion, ethyl	1	2.13	<0.01	0.01
Field Corn: Stalks				
Chlorinated Hydrocarbons, 270 Sites				
Chlordane	14	5.19	0.01	0.01-0.52
o,p'-DDE	2	0.74	<0.01	0.01
p,p'-DDE	33	12.22	<0.01	0.01-0.36
o,p'-DDT	33	12.22	0.01	0.01-0.28
p,p'-DDT	53	19.63	0.03	0.01-2.20
DDTR	54	20.00	0.04	0.01-2.88
Dieldrin	42	15.56	<0.01	0.01-0.09
Heptachlor	1	0.37	<0.01	0.06
Heptachlor epoxide	5	1.85	<0.01	0.01-0.12
p,p'-TDE	29	10.74	<0.01	0.01-0.30
Toxaphene	12	4.44	0.02	0.09-1.35
Organophosphates, 228 Sites				
Malathion	1	0.44	<0.01	0.04

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TABLE 11 (cont'd). *Chlorinated hydrocarbon and organophosphate residues in crops, all sites, FY-70*

Pesticide	No. Times Pesticide Detected	Percent Occurrence	Arith. Mean Conc., ppm	Range of Detected Residues, ppm
Cotton: Seeds				
Chlorinated Hydrocarbons, 39 Sites				
p,p'-DDE	13	33.33	2.57	0.01-100.01
o,p'-DDT	14	35.90	0.01	0.01- 0.18
p,p'-DDT	20	51.28	0.07	0.01- 1.02
DDTR	20	51.28	2.65	0.01-100.05
Dieldrin	2	5.13	<0.01	0.01
p,p'-TDE	8	20.51	<0.01	0.01- 0.02
Toxaphene	12	30.77	0.15	0.05- 1.85
Organophosphates, 37 Sites				
DEF	17	45.95	0.11	0.02-1.10
Parathion, ethyl	3	8.11	<0.01	0.01-0.03
Parathion, methyl	7	18.92	0.01	0.01-0.08
Mixed Hay				
Chlorinated Hydrocarbons, 29 Sites				
Aldrin	1	3.45	<0.01	0.07
Chlordane	5	17.24	0.07	0.05-1.19
p,p'-DDE	11	37.93	0.01	0.01-0.19
o,p'-DDT	11	37.93	0.01	0.01-0.04
p,p'-DDT	20	68.97	0.02	0.01-0.13
DDTR	20	68.97	0.04	0.01-0.36
Dieldrin	19	65.52	0.01	0.01-0.11
Endrin	1	3.45	<0.01	0.12
Heptachlor	1	3.45	<0.01	0.02
p,p'-TDE	6	20.69	<0.01	0.01-0.02
Toxaphene	4	13.79	0.01	0.05-0.13
Organophosphates, 29 Sites: 0 Detections				
Soybeans: Beans				
Chlorinated Hydrocarbons, 178 Sites				
Chlordane	3	1.69	<0.01	0.01-0.10
Dieldrin	69	38.76	0.01	0.01-0.09
Endrin	15	8.43	<0.01	0.01-0.14
Heptachlor	2	1.12	<0.01	0.01
Heptachlor epoxide	12	6.74	<0.01	0.01-0.05
Ramrod	1	0.56	<0.01	0.24
Toxaphene	19	10.67	0.02	0.08-0.41
Trifluralin	8	4.49	<0.01	0.01-0.09
Organophosphates, 137 Sites: 0 Detections				

NOTE: Samples were examined for organophosphates only when use records indicated they had been applied.
All residues on dry-weight basis.

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Baseline Concentrations of Polychlorinated Biphenyls and DDT in Lake Michigan Fish, 1971 [1]

Gilman D. Veith [2]

ABSTRACT

Responding to the recommendations of the Lake Michigan Interstate Pesticide Committee, the author aimed to establish baseline data on polychlorinated biphenyls (PCB's) and DDT in Lake Michigan fish in 1971. Because the past 2 years had witnessed unprecedented legislative action to protect food resources and other aquatic species near the top of the food chain from persistent hazardous chemicals, the author also attempted to gauge the impact of cooperative legislative action on the quality of large lakes.

Thirteen species of fish taken from 14 regions of Lake Michigan in the fall of 1971 were analyzed for PCB's and DDT analogs. Mean wet-weight concentrations of PCB's similar to Aroclor 1254 ranged from 2.7 ppm in rainbow smelt to 15 ppm in lake trout. Most trout and salmon longer than 12 inches contained PCB's at concentrations greater than the tolerance level of 5 ppm established by the Food and Drug Administration, U.S. Department of Health, Education, and Welfare. Mean concentrations of total DDT ranged from less than 1 ppm in suckers to approximately 16 ppm in large lake trout. The presence of the major chlorinated hydrocarbons was confirmed by gas-liquid chromatography/mass spectrometry; additional PCB confirmations were obtained through perchlorination. The most abundant PCB's were tetra-, penta-, hexa-, and heptachlorobiphenyls which are similar to commercially prepared Aroclor 1254; lesser chlorinated PCB's were present in fish from nearshore waters.

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Introduction

This paper identifies and quantifies the most abundant organochlorine compounds, particularly polychlorinated biphenyls (PCB's) and DDT, in Lake Michigan fish in 1971. By establishing data on PCB's and DDT in Lake Michigan fish as recommended by the Lake Michigan Interstate Pesticide Committee, the author of the present study aimed to develop a 1971 baseline to predict trends of these chemicals in the lake. Lake Michigan contains much higher concentrations of potentially hazardous and persistent organic chemicals than the other Great Lakes, in part because of their widespread usage in the watershed and their disproportionally brief flushing period and low biomass density. Previous studies have shown that fish from Lake Michigan approach the action levels for dieldrin set by the Food and Drug Administration (FDA), U.S. Department of Health, Education, and Welfare (*1*); a major percentage of Lake Michigan fish exceeded the 5 ppm action level for DDT in 1969 (*2*). Similarly, Veith (*3*) has shown that PCB concentrations similar to Aroclor 1254 were greater than 15 ppm or three times the FDA action level in large fish captured from Lake Michigan in 1969.

Despite the comparatively high levels of DDT, dieldrin, and PCB's in Lake Michigan, there is no unequivocal evidence that they are endangering aquatic life. Concentrations of these chemicals appear to be below 10 parts per trillion (ppt) in the pelagic water and less than 100 ppt in nearshore waters. However, considerable indirect evidence suggests that the buildup of organochlorine compounds may threaten biological resources of the lake. Other reports have reviewed the chronic toxicity of pesticides and PCB's (*4-7*).

States surrounding Lake Michigan have made a major effort to restock the lake with brown, lake, and rainbow trout and coho and chinook salmon. Between 1963 and 1970, over 600,000 rainbow trout were released by Wisconsin alone (*8,9*). However, Reinert (*2*) previously noted that DDT and dieldrin levels in eggs of these fish are similar to concentrations which inhibited reproduction in the studies of Burdick et al. (*10*) and Macek (*11*). Johansson et al. (*12*) have shown that 15 ppm PCB's (lipid basis) in salmon eggs produced mortality in 50 percent of the samples tested. Death can be expected in all eggs when the PCB lipid content reaches 25 ppm.

Although continued stocking of fish may maintain a food resource, many fish contain residue body burdens which make them unfit for consumption. The effect of these fish on mink production in the North Central States has been studied in detail: before DDT and dieldrin concentrations in these fish had been well documented, Hartsough (*13*) indicated that the fish were suspected to inhibit mink reproduction; Aulerich et al. (*14*) clearly demonstrated that the fish had been the cause of the minks' reproductive failure; and Aulerich and Ringer (*15*) reported that DDT and DDD did not have significant adverse effects on mink. Furthermore, dieldrin was lethal to mink at 2.5 ppm in the food when fed for extended periods, but did not appear to affect reproduction at twice this concentration during the gestation period. Aulerich et al. concluded that feeding coho salmon to mink did not cause reproduction problems, but that the disorder is associated with other species of fish and ". . . appears to be dependent upon the species of fish and its environment" (*16*). Finally, after the earlier reports that PCB's were present in Lake Michigan fish, Ringer et al. (*17*) demonstrated that 10 ppm Aroclor 1254 in coho salmon produced 71 percent mortality in mink and that a mixture of 10 ppm PCB's and 0.5 ppm dieldrin in coho feed produced 100 percent mortality. No kits were born alive when the diet contained 5 ppm or more Aroclor 1254 alone. This clearly indicates that biological resources of Lake Michigan may seriously endanger other species even though concentrations of toxicants are not severe enough to produce readily discernible effects within the aquatic communities.

Equally important is the coincidence of high chlorinated hydrocarbon levels in herring gull and other bird populatons coupled with reproductive failures and subsequent population decline (*18*). Anderson (*19*) found that the eggs of the Great Lakes herring gull contained the highest chlorinated hydrocarbon levels ever reported for that species. He also found that the degree of eggshell thinning in the Lake Michigan gull, whose population declined dramatically in the early 1960's, varied from 9 percent in 1953-56 to 18 percent in 1965. In comparison, eggs of gulls on Lake Huron and Lake Superior have exhibited shell thinning of 7 percent and 8 percent, respectively, and those from gulls on the East Coast have remained essentially unchanged. Double-crested cormorants from Wisconsin had eggshells 20 percent thinner than those of gulls, and their eggs had the highest DDE concentrations of any cormorant eggs sampled from interior North America. Golden eagles, which feed primarily on mammals, do not show eggshell thinning as dramatic as that of bald eagles, which feed on fish (*19*).

Lake Michigan is the only Great Lakes watershed where major persistent chemicals have been curtailed. Although use of chlorinated pesticides in agriculture was probably diminishing in the late 1960's, the Lake Michigan Enforcement Conference recommended regulatory actions on many uses in 1968. This recommendation led to restrictions on DDT including its sale in Illinois, Michigan, and Wisconsin. A more detailed summary is presented by Lueschow (*20*). Monsanto Company, the sole producer of PCB's in the United States, restricted PCB sales in 1970; by April 1971 they were sold only to close-system users.

To measure the impact of the unprecedented cooperative legislative action regarding these chemicals, and to establish baseline data, the Lake Michigan Interstate Pesticide Committee recommended that this study be funded.

Sampling Procedures

Fish were collected in September and October 1971 with gill nets and pond nets from the four regions of Lake Michigan outlined in Figure 1. Whole fish were stored frozen (−20° C) in aluminum foil or polyethylene bags for 60 days or less and homogenized while frozen by repeatedly passing them through a meat grinder. All metal surfaces were rinsed with acetone, polyethylene bags were examined for interferences, and the grinder bearing and seal were checked periodically to assure that the sample was not contaminated during storage or preparation.

Analytical Procedures

REAGENTS

Sodium sulfate (Fisher Scientific Co.) was washed with three volumes of 1:1 hexane-acetone and dried at 130° C. To prevent further contamination from cap liners or containers, the Na_2SO_4 was stored in large glass bottles with aluminum foil liners in the cap.

The florisil (Kensington Chemical, Fisher Scientific Co.) was extracted in an all-glass Soxhlet extractor for 24 hours with the azeotrope of hexane and acetone to remove traces of organic impurities. The solvent was evaporated from the florisil at 100° C, and the solid was heated at 650° C for 2.5 hours for activation. If not used immediately after heating, the florisil was heated to 105° C before use.

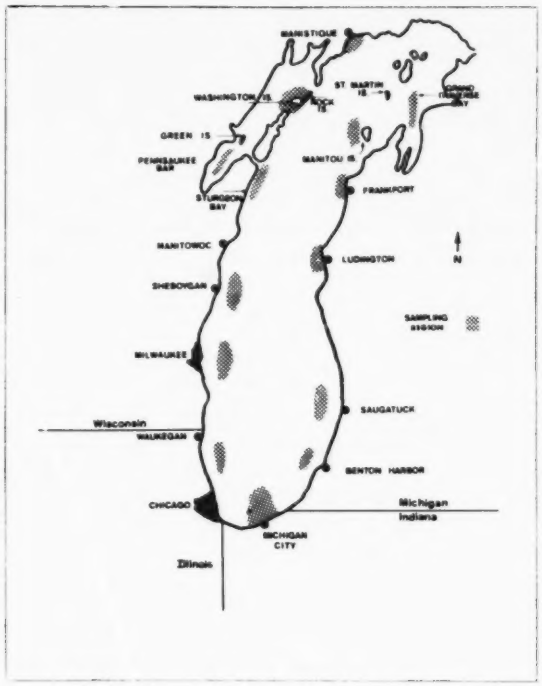

FIGURE 1. *Sampling regions for collecting fish, Lake Michigan—1971*

Other analytical components included:

Silicic acid:	Mallinckrodt Chemical, AR grade, Ramsey and Patterson. Used directly from reagent bottle.
Hexane:	Skelly B. Redistilled in glass from Dri-Sodium, Fisher Scientific Co.
Acetone:	Fisher Scientific Co., MCB. Redistilled in glass from Dri-Sodium, Fisher Scientific Co.
Ethyl ether and methylene chloride:	Mallinckrodt Chemical. Pesticide-quality solvents. Used directly from reagent bottle after periodic checks showed no interferences.
Glass wool:	Soaked in acetone, rinsed with 1:1 acetone:hexane mixture.
Glassware:	Washed thoroughly with hot detergent; rinsed once with hot water, twice with distilled water, again with 1:1 mixture of redistilled acetone:hexane.

PREPARATION OF SAMPLES

Procedures to extract and remove the bulk of the lipids have been described previously (*21*). Because of the high relative concentration of *p,p'*-DDE in Lake Michigan fish, DDE was quantitated directly by diluting 10 percent of the nonpolar Florisil eluate to the appropriate volume for gas-liquid chromatographic (GLC) analysis. PCB's were separated from TDE and DDT isomers with a modified Armour and Burke procedure which omitted Celite 545 (*22*).

Quantitative gas chromatographic analyses were conducted on an Aerograph 17:5-20 gas chromatograph equipped with dual concentric-tube electron-capture detectors (^{3}H, 250 mc). Columns were 2.0-m-by-1.8-mm-ID glass coils packed with 3 percent OV-101 on 120/140-mesh Gas-Chrom Q. The carrier gas, purified N_2, was maintained at 20 ml/min; the injector, column, and detector temperatures were 240°, 180°, and 220° C, respectively. Chromatograms were recorded on a Varian model A-25 dual pen recorder.

Previous work (*21*) showed that fish from Lake Michigan contain mixtures of PCB's that closely resemble the Aroclor 1254 produced by Monsanto Company, although PCB's both heavier and lighter than those most abundant in Aroclor 1254 were also present. The fish extracts contain predominantly those PCB's which elute at 70, 84, a doublet of 98 and 104, 125, 146, and 176; peak height of *p,p'*-DDE is represented here as 100 (Fig. 2). The presence of DDE precluded the use of the 98 and 104 PCB components in the quantitation, and PCB's based on Aroclor 1254 were determined by summing the heights of the 70, 84, 125, 146, and 174 PCB components when peak height of DDE is 100. This method also decreased the effect of minor compositional variations on the analytical result.

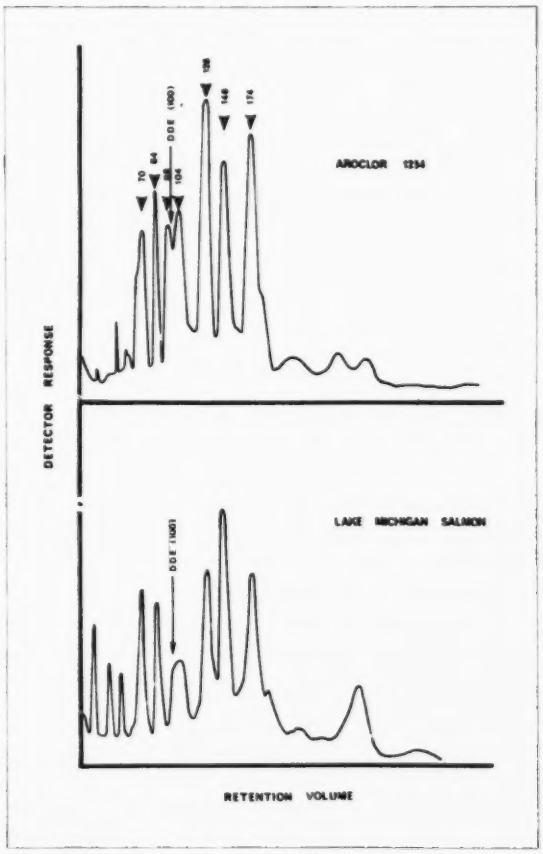

FIGURE 2. *Chromatograms of PCB mixtures in Aroclor 1254 and fish from Lake Michigan*

Recovery of PCB's from fish tissue averaged 85.1 ± 4.3 percent, whereas recovery of DDE was greater than 90 percent. The precision of the method outlined above is summarized in Table 1, which lists means and standard deviations of the analyses of six replicates of several fish species for PCB's, DDT, and lipids. The standard deviation for PCB analyses ranged from 5 percent in smaller fish to 14 percent in large coho salmon. The decrease in precision in analyses of large coho resulted from the difficulty of homogenizing larger fish. Precision was poorest in DDT analyses, where the standard deviation ranged from 8 to 23 percent with a mean of approximately 14 percent. This reduced precision results from losses during silicic acid chromatography which is used to quantitate the TDE and DDT isomers. The precision of DDE analyses was greater than those for DDT analyses, which was anticipated because of the fewer manipulations of the extracts. The standard deviation ranged from 7 to 18 percent, but the average deviation was approximately 10 percent. Because of the relatively simple procedure, lipid analyses were most precise, exhibiting standard deviations from 5 to 7 percent.

TABLE 1. *Precision of chlorinated hydrocarbon determinations for PCB's, DDE, DDT, and lipids in selected fish, Lake Michigan—1971*

Species	No. Replicates	Aroclor 1254	*p,p'*-DDE	*p,p'*-DDT	Lipid, %
Coho salmon (25 in.)	6	15.2±2.2	7.5±0.6	3.2±0.6	4.2±0.2
Coho salmon (27 in.)	6	13.1±1.3	5.5±0.4	1.8±0.4	10.0±0.6
Whitefish (13 in.)	6	4.1±0.2	0.35±0.04	0.56±0.04	16.2±0.9
Bloater (10 in.)	6	5.7±0.4	3.4±0.3	2.2±0.3	18.2±1.3
Alewife (8 in., composite)	6	4.0±0.2	1.1±0.2	1.0±0.2	5.7±0.3

NOTE: In columns 3-6, first number represents mean, second represents standard deviation.
Residues are ppm wet weight.

The determinable limit for PCB analysis was approximately 0.1 ppm; limits for *p,p'*-DDT, *o,p'*-DDT, *p,p'*-TDE, and *p,p'*-DDE were approximately 0.05 ppm.

CONFIRMATION OF MAJOR COMPONENTS

Major components of Lake Michigan fish extracts were characterized for a limited number of composite samples by standard gas-liquid chromatography/mass spectrometry techniques. In addition, the presence of PCB's in samples from each collection area was confirmed by perchlorination of PCB's to decachlorobiphenyl and subsequent analysis of the product by GLC (*23*). Aliquots of the hexane fraction of silicic acid columns were evaporated to dryness in a 5-ml vial fitted with a teflon-lined screw cap. Antimony pentachloride (0.2 ml) was added to the residue, and the vial was sealed and held at 180° C for 6 hours. Approximately 1 ml 6N MCl was added to the products to remove the $SbCl_5$ and the solution was extracted with five 1-ml hexane portions. The hexane was passed through a disposable pipette containing anhydrous Na_2SO_4 to remove traces of the aqueous solution. The sample was collected in a graduated centrifuge tube and diluted to the proper volume for GLC analysis. This technique also provided semiquantitative information for PCB's to supplement direct GLC analysis of the extracts. For those samples which contained PCB's similar to Aroclor 1254, estimates of total PCB's by perchlorination were within 15 percent of direct GLC analysis.

Results and Discussion

Approximately 850 fish were analyzed for PCB mixtures most closely resembling Aroclor 1254; a summary is presented in Table 2. Mean concentrations ranged from 2.7 ppm in smelt to 15.5 ppm in lake trout. Larger fish, such as brown, lake, and rainbow trout and chinook and coho salmon, contained PCB's at mean concentrations two to three times the 5 ppm action level established by FDA (*1*). Mean PCB concentrations in redhorse suckers, smelt, and whitefish were considerably less than 5 ppm. Mean concentrations in the alewife, carp, chub, and yellow perch were approximately 5 ppm; the range was 4.2-6.0 ppm. As expected, PCB levels increased with the percentage of fat and size of fish.

In Lake Michigan fish the mean concentration of total DDT, the sum of *p,p'*-DDT, *o,p'*-DDT, *p,p'*-TDE, and *p,p'*-DDE, ranged from 0.9 ppm in carp to 7.1 ppm in lake trout (Table 2). As with PCB's, fish with higher lipid concentrations contained greater concentrations of DDT.

The ratio of PCB's to total DDT ranged from 1.3 in redhorse suckers caught primarily in the northern waters to 7.6 in carp. The ratio of PCB's to DDT in the majority of the fish was between 1.7 and 2.8, and only in the carp, redhorse, yellow perch, and white sucker did the ratios fall outside this range. This ratio may become important in future studies to determine the rates at which the chemicals are eliminated from the Lake Michigan system.

Mean ratios of *o,p'*-DDT to *p,p'*-DDT ranged from 0.1 to 0.3; this ratio in the majority of the fish was 0.2. Since technical DDT generally contains about 30 percent of the *o,p'*-DDT isomer (ratio, 0.4), data from Lake Michigan fish suggest that degradation, other removal mechanisms, or both in the lake are slightly greater for the *o,p'* isomer than for the *p,p'* isomer. More than 80 percent of the total DDT residue is accounted for by *p,p'*-DDE and *p,p'*-DDT.

Not only did PCB concentrations vary considerably among the 13 species captured, but the range of PCB concentrations in a single lake species was generally

greater than 100 percent. The concentration range in red suckers was less, but all were captured in the same region of the lake. Although some variation in concentrations is expected because of the normal analytical error, the much larger ranges in Table 2 are undoubtedly due to other factors that limit usefulness of the mean concentrations presented. Previous research has shown that the lipid content, size of fish, season of capture, and concentration in the water may affect considerably the observed concentration of chlorinated hydrocarbons in tissue (2).

CHLOROBIPHENYLS

Regional variation in PCB concentrations and variations due to lipid content for each species are shown in Table 3. The wet-weight concentration of PCB's in ale-

TABLE 2. *Major chlorocarbons in fish, Lake Michigan—1971*

Species [1]	No. Fish Analyzed	Mean Fish Weight, g	Mean Lipid, %	Mean PCB's	Mean DDE	Mean ΣDDT	Mean PCB/ ΣDDT	Mean DDE/ ΣDDT	Mean *o,p'*-DDT/ *p,p'*-DDT
Alewife	85	100	6.5[3.9]	4.6[2.1]	1.7[0.8]	2.2[1.1]	2.4	0.8	0.2
Bloater	287	249	20.0[5.9]	6.0[2.2]	2.5[1.1]	3.8[2.8]	2.2	0.7	0.2
Brown trout	17	3,650	15.5[4.1]	7.3[2.8]	2.7[1.0]	4.2[1.6]	1.8	0.6	0.1
Carp	42	2,160	10.0[7.0]	4.2[3.6]	0.7[0.9]	0.9[1.2]	7.6	0.8	0.3
Chinook salmon	21	3,100	5.0[3.9]	11.4[4.0]	5.2[1.5]	6.8[2.5]	1.7	0.8	0.2
Coho salmon	56	2,720	6.5[2.1]	11.5[5.7]	4.8[2.3]	6.3[2.8]	2.1	0.7	0.2
Lake trout	134	1,620	16.6[4.3]	15.5[3.3]	5.0[2.8]	7.1[3.7]	2.5	0.7	0.2
Yellow perch	44	148	6.1[1.7]	5.8[3.5]	1.0[0.6]	1.6[1.1]	4.8	0.8	0.1
Rainbow trout	11	4,190	18.4[3.3]	9.3[4.1]	3.4[1.3]	4.2[1.8]	2.3	0.8	0.2
Redhorse sucker	16	902	8.6[1.2]	3.0[0.7]	1.6[0.5]	2.6[0.7]	1.3	0.6	0.2
Smelt	38	51	5.8[1.8]	2.7[1.3]	0.8[0.4]	1.2[0.6]	2.6	0.7	0.1
White sucker	51	1,130	5.9[2.8]	3.9[3.6]	1.0[0.5]	1.6[1.2]	3.4	0.7	0.1
Whitefish	43	1,170	17.6[4.4]	3.0[1.9]	0.8[0.3]	1.4[0.6]	2.8	0.7	0.2

NOTE: Expressions in brackets represent standard deviations.
Residues are ppm wet weight.
[1] Scientific names appear in Table 3.

TABLE 3. *Mean concentrations of PCB's and DDT in fish, Lake Michigan—1971*

Location	Capture Date	No. Fish Analyzed	PCB's	Percentage Fish Above 5 ppm PCB's	PCB's, Lipid Weight	*p,p'*-DDE	*p,p'*-TDE	*p,p'*-DDT	*o,p'*-DDT	Total DDT	Percentage Fish Above 5 ppm DDT
Alewife (*Alosa pseudoharengus*)											
Michigan City	10/15	10	4.4[2.0]	40	164	1.4	0.19	0.5	0.08	2.2	10
Benton Harbor	9/2	10	4.8[1.1]	40	60	1.8	0.23	0.5	0.08	2.7	0
Waukegan	8/23	2	2.5[0.1]	0	47	1.0	0.18	0.5	0.07	1.6	0
Saugatuck	4/11	12	5.3[2.2]	41	51	1.8	0.22	0.8	0.10	2.7	11
Sheboygan	10/15	4	5.5[1.4]	50	79	2.2	0.20	0.7	0.07	3.2	0
Ludington	7/3	16	4.4[1.4]	18	207	ND	ND	ND	ND	ND	ND
Frankfort	10/5	10	3.7[1.2]	20	62	1.3	0.16	0.4	0.06	1.9	0
Manitou Island	9/10	3	3.8[2.2]	33	51	3.2	0.33	1.3	0.16	5.0	30
Rock Island	9/11	3	8.9[12.0]	66	182	1.1	0.11	0.3	0.04	1.5	0
St. Martin Island	9/11	6	3.5[1.3]	16	82	1.0	0.14	0.3	0.05	1.5	0
Brown trout (*Salmo trutta*)											
Michigan City	10/15	1	11.9[0.0]	100	51	3.7	0.70	1.7	0.22	8.4	100
Sheboygan	7/13	5	7.9[3.0]	100	42	2.6	0.46	1.2	0.18	4.4	25
Gills Rock	9/16	10	6.7[2.5]	70	54	2.8	0.48	1.0	0.14	4.4	40
Carp (*Cyprinus carpio*)											
Michigan City	11/29	2	11.0[0.2]	100	72	3.3	0.81	0.3	0.14	4.6	50
Saugatuck	10/15	15	4.6[4.8]	26	71	0.6	0.20	0.1	0.02	0.9	0
Sheboygan	7/23	11	1.7[0.8]	0	30	0.2	0.07	0.0	0.01	0.3	0
Pensaukee Bar	11/1	9	4.2[1.4]	33	30	0.8	0.19	0.0	0.01	1.0	0
Manitou Island	9/16	5	5.8[0.8]	80	30	ND	ND	ND	ND	ND	ND
Bloater (*Coregonus hoyi*)											
Benton Harbor	9/2	10	5.0[1.2]	60	24	2.5	0.31	1.5	0.19	4.5	30
Saugatuck	6/16	18	8.1[1.9]	88	46	1.9	0.47	1.8	0.19	4.3	37
Saugatuck	6/18	24	7.8[2.2]	95	43	2.4	0.63	2.4	0.25	5.7	64
Saugatuck	6/19	15	6.9[1.8]	86	34	1.8	0.47	2.5	0.31	5.1	66
Milwaukee	9/19	11	4.6[1.2]	36	28	3.4	0.36	2.0	0.26	6.0	88
Sheboygan	7/13	13	5.1[1.5]	61	31	1.3	0.40	2.2	0.24	4.1	50
Sheboygan	7/22	13	6.1[1.8]	76	21	3.4	0.34	2.0	0.24	5.9	81

(Continued next page)

TABLE 3 (cont'd.). *Mean concentrations of PCB's and DDT in fish, Lake Michigan—1971*

Location	Capture Date	No. Fish Analyzed	PCB's	Percentage Fish Above 5 ppm PCB's	PCB's, lipid weight	*p,p'*-DDE	*p,p'*-TDE	*p,p'*-DDT	*o,p'*-DDT	Total DDT	Percentage Fish Above 5 ppm DDT
Sheboygan	8/19	6	3.8[0.6]	0	15	2.6	0.35	1.3	0.16	4.4	20
Sheboygan	8/27	7	5.0[1.3]	57	23	3.2	0.47	2.3	0.28	6.2	80
Sheboygan	10/15	6	3.7[0.8]	0	21	2.4	0.28	1.7	0.17	4.5	42
Ludington	7/3	43	7.4[1.8]	93	41	2.0	0.58	2.2	0.28	5.0	46
Frankfort	10/5	8	4.7[0.7]	12	28	2.2	0.33	1.2	0.16	3.8	0
Manitou Island	9/10	10	4.6[1.1]	30	24	3.1	0.50	1.8	0.26	5.6	50
Washington Island	9/9	6	4.1[0.6]	0	16	3.2	0.34	1.9	0.18	5.6	60
Rock Island	9/11	6	5.8[2.5]	66	97	2.8	0.36	1.1	0.08	4.4	20
Rock Island	9/14	7	5.6[1.6]	57	23	2.7	0.42	2.0	0.22	5.4	50
Rock Island	9/16	8	4.0[0.7]	12	18	2.8	0.29	1.3	0.14	4.5	40
St. Martin Island	7/19	9	3.4[0.6]	0	16	2.2	0.34	1.1	0.17	3.8	0
Manistique	5/27	9	4.8[0.7]	33	26	2.9	0.42	1.8	0.14	5.2	80
Chinook salmon (*Oncorhynchus tschawytscha*)											
Milwaukee	10/15	1	24.0[0.0]	100	117	6.6	1.67	4.7	0.53	13.6	100
Manitowoc	10/21	8	11.3[3.1]	100	209	6.3	0.62	1.2	0.21	8.3	100
Strawberry Creek	10/21	10	9.9[2.8]	100	373	4.5	0.39	1.0	0.17	8.0	88
Gills Rock	9/16	2	12.7[0.7]	100	278	5.5	0.44	1.2	0.20	7.3	100
Coho salmon (*Oncorhynchus kisutch*)											
Michigan City	4/17	8	3.6[1.7]	12	51	0.8	0.17	0.6	0.08	1.6	0
Michigan City	9/27	8	17.3[8.4]	87	255	5.3	0.46	1.2	0.20	7.2	85
Michigan City	10/7	6	14.0[4.0]	100	349	4.5	0.41	1.4	0.18	6.5	60
Sheboygan	10/21	9	12.1[2.8]	100	276	6.6	0.57	1.4	0.27	8.8	100
Ludington	8/28	4	11.2[3.3]	100	108	6.8	0.39	0.9	0.19	8.3	100
Platte River	10/7	10	12.9[1.3]	100	226	5.5	0.48	1.4	0.24	7.6	100
Gills Rock	9/16	11	12.6[4.1]	90	166	4.9	0.45	1.2	0.20	6.7	87
Lake trout (*Salvelinus namaycush*)											
Michigan City	10/15	4	14.9[2.0]	100	89	2.9	0.88	3.1	0.35	7.3	100
Michigan City	9/8	3	21.2[6.8]	100	121	9.5	1.12	3.9	0.45	14.9	100
Saugatuck	6/21	14	11.9[3.8]	100	70	4.7	0.65	2.1	0.27	7.6	88
Saugatuck	7/10	7	15.5[2.4]	100	78	6.9	0.70	2.0	0.24	9.8	100
Saugatuck	10/1	9	18.7[4.7]	100	113	6.7	0.84	2.8	0.27	10.6	100
Milwaukee	9/14	1	21.2[0.0]	100	90	10.1	0.96	3.0	0.47	14.5	100
Milwaukee	9/19	7	21.1[6.0]	100	114	10.6	1.05	3.3	0.45	15.4	100
Milwaukee	10/15	12	10.4[3.6]	100	127	2.3	0.44	1.3	0.15	4.2	20
Sheboygan	7/1	1	14.9[0.0]	100	58	ND	ND	ND	ND	ND	ND
Sheboygan	7/13	36	12.5[3.2]	100	82	4.3	0.51	1.7	0.24	6.8	64
Ludington	7/1	10	8.1[1.8]	100	51	3.3	0.52	1.6	0.22	5.6	60
Ludington	7/4	8	8.5[1.7]	100	58	3.2	0.63	2.0	0.30	6.1	66
Grand Traverse Bay	10/19	8	11.3[5.3]	75	56	6.0	0.73	2.0	0.30	9.0	77
Green Island	7/21	19	9.0[1.7]	100	48	3.8	0.50	1.5	0.21	6.0	72
Gills Rock	9/16	10	14.7[6.4]	100	83	5.5	0.62	1.9	0.24	8.3	62
Yellow perch (*Perca flavescens*)											
Michigan City	10/15	14	4.2[0.7]	14	72	0.8	0.15	0.4	0.04	1.3	0
Waukegan	8/28	9	6.1[1.5]	88	78	ND	ND	ND	ND	ND	ND
Milwaukee	10/13	10	10.9[3.1]	90	203	1.1	0.30	0.7	0.08	2.1	0
Ludington	7/6	3	6.2[1.3]	100	139	2.2	0.30	0.9	0.13	3.6	0
Frankfort	10/12	2	5.4[1.8]	50	69	1.7	0.43	2.2	0.14	4.5	0
Pensaukee Bar	8/25	10	2.7[2.1]	10	49	0.4	0.10	0.0	0.01	0.5	0
Rainbow trout (*Salmo gairdneri*)											
Michigan City	10/15	1	12.0[0.0]	100	66	ND	ND	ND	ND	ND	ND
Gills Rock	9/16	9	8.8[4.3]	77	47	3.1	0.34	0.9	0.16	4.5	40
Redhorse (*Moxostoma* sp.)											
Rock Island	9/11	7	2.8[0.9]	0	33	1.7	0.30	0.6	0.09	2.7	0
St. Martin Island	9/11	9	3.2[0.5]	0	37	1.5	0.35	0.8	0.09	2.7	0
Rainbow smelt (*Osmerus eperlanus modrax*)											
Michigan City	10/15	15	3.2[0.9]	0	45	0.9	0.11	0.4	0.04	1.4	0
Sheboygan	10/15	3	0.7[0.2]	0	18	0.6	0.12	0.3	0.03	1.0	0
Green Island	7/21	5	2.6[1.1]	0	57	0.7	0.12	0.2	0.02	1.0	0
Rock Island	9/11	8	2.9[1.7]	25	49	1.0	0.14	0.5	0.05	1.6	0
St. Martin Island	7/19	4	1.3[0.3]	0	31	0.7	0.09	0.2	0.04	1.0	0
White sucker (*Catostomus commersoni*)											
Michigan City	10/15	6	10.6[4.0]	100	100	1.8	0.32	1.8	0.08	4.6	66
Saugatuck	10/15	3	6.0[2.9]	66	149	0.7	0.14	0.2	0.03	1.0	0
Saugatuck	10/18	5	2.3[0.4]	0	40	ND	ND	ND	ND	ND	ND
Pensaukee Bar	8/6	7	3.2[3.1]	14	57	0.3	0.15	0.2	0.04	0.7	0
Grand Traverse Bay	10/19	14	2.3[0.7]	0	68	0.4	0.31	0.4	0.03	2.1	0
Green Island	7/21	1	2.1[0.0]	0	20	0.7	0.19	0.4	0.08	1.3	0
Rock Island	9/11	14	2.5[0.9]	0	46	0.9	0.20	0.3	0.04	1.4	0

(Continued next page)

TABLE 3 (cont'd.). *Mean concentrations of PCB's and DDT in fish, Lake Michigan—1971*

Location	Capture Date	No. Fish Analyzed	PCB's	Percentage Fish Above 5 ppm PCB's	PCB's, lipid weight	*p,p'*-DDE	*p,p'*-TDE	*p,p'*-DDT	*o,p'*-DDT	Total DDT	Percentage Fish Above 5 ppm DDT
Lake whitefish (*Coregonus clupeaformis*)											
Michigan City	10/15	4	6.1[0.9]	100	25	0.5	0.32	0.5	0.06	1.4	0
Saugatuck	6/19	7	2.7[0.5]	0	15	0.6	0.21	0.4	0.08	1.3	0
Saugatuck	6/21	2	3.1[1.3]	0	18	ND	ND	ND	ND	ND	ND
Grand Haven	9/6	7	5.8[0.9]	71	25	0.7	0.38	0.8	0.10	1.9	0
Grand Traverse Bay	10/19	13	1.8[0.3]	0	13	1.2	0.25	0.4	0.08	2.0	0
Rock Island	9/11	10	1.5[0.2]	0	9	0.7	0.16	0.4	0.05	1.4	0

NOTE: Expressions in brackets represent standard deviations.
ND = not determined.
Residues are ppm wet weight.

wives was greater in southern Lake Michigan than in the northern regions, although anomalies are apparent. Most alewives captured south of a line between Saugatuck and Sheboygan contained between 4.4 and 5.5 ppm PCB's, whereas those caught north of the line contained between 3.5 and 4.4 ppm. An interesting exception occurred in alewives from Rock Island just off the Door County Peninsula in Wisconsin; mean PCB concentration was 8.9 ppm.

Analysis of brown trout suggested similar trends: those from Michigan City at the southern end of the lake contained 11.9 ppm PCB's, whereas those from Sheboygan and Gills Rock contained 7.9 and 6.7 ppm PCB's, respectively.

Carp from Michigan City also had higher levels of PCB's than had those from the northern region. In contrast to the 11.0 ppm found in the Michigan City carp, those from Saugatuck and Sheboygan contained 4.6 and 1.7 ppm, respectively.

PCB's in bloaters in southern Lake Michigan ranged from 4.6 ppm near Milwaukee to 8.1 ppm near Saugatuck. In general, bloaters from the northern regions had concentrations below 5 ppm. The concentration of PCB's in the five groups of bloaters collected near Sheboygan during a 3-month period varied from 3.7 to 6.1 ppm, although the mean was below 5 ppm; no trend was indicated. The variation is somewhat less when data are expressed on a lipid basis; for example, PCB concentrations in the August 27 and October 15 bloaters were 5.0 and 3.7 ppm wet weight, respectively. In contrast, the concentration of PCB's in lipids was 23 ppm and 21 ppm, respectively. Thus much of the observed variation is caused by the variation in lipid content of fish.

All chinook salmon captured in Wisconsin contained more than 5 ppm PCB's; mean concentrations ranged from 9.9 ppm in Strawberry Creek (Sturgeon Bay) to 24 ppm at Milwaukee.

In concentrations of PCB's among coho salmon, authors observed little evidence of a trend dependent upon sampling region. Except for coho caught early in 1971 near Michigan City, mean concentrations of PCB's ranged from 11.2 ppm in salmon near Ludington to 17.3 ppm in those near Michigan City.

Among lake trout PCB concentrations were greatest in those from Michigan City, Saugatuck, and Milwaukee, where mean concentrations were generally between 15 and 21 ppm. Trout from the northern areas such as Sheboygan, Ludington, Grand Traverse Bay, and Gills Rock contained considerably less, and mean concentrations ranged between 8 and 15 ppm.

Mean concentration of PCB's was unexpectedly high, 10.9 ppm, in the 10 yellow perch caught near Milwaukee. Perch from other regions averaged less by a factor of two, and those from lower Green Bay contained 2.7 ppm.

In seven Rock Island redhorse, PCB residues averaged 2.8 ppm. In nine specimens from St. Martin Island, mean concentration was 3.2 ppm.

Rainbow trout were caught only near Michigan City and Gills Rock. The Michigan City rainbow trout had 12.0 ppm PCB's, whereas those from Gills Rock averaged only 8.8 ppm.

Concentrations of PCB's in white suckers and smelt were generally between 2 and 4 ppm, although the average concentration was 6.0 ppm in the three white suckers from Saugatuck on October 15 and 10.6 ppm in the six from Michigan City the same day. Except for whitefish caught at Grand Haven and Michigan City, the PCB concentration in whitefish was less than 3.1 ppm.

DDT AND ANALOGS

Concentrations of *p,p'*-DDT, *o,p'*-DDT, *p,p'*-TDE, and *p,p'*-DDE are presented in Table 3 along with the total DDT and percentage of fish that contained residues above the 5ppm action level established by FDA (*1*). Total DDT in alewives ranged from 1.6 ppm near Waukegan to 5.0 ppm near the Manitou Islands. There was no trend in the variations according to region. A brown trout from Michigan City contained 8.4 ppm total DDT, whereas those from Sheboygan and Gills Rock averaged 4.4 ppm. Except for the carp from Michigan City, which averaged 4.6 ppm total DDT, average concentrations in Lake Michigan carp were 1.0 ppm or less.

Total DDT in bloaters ranged from 3.8 ppm at Frankfort and St. Martin Island to 6.2 ppm at Sheboygan. There are no trends for DDT in chubs (Table 3). Except for eight coho salmon caught near Michigan City in the spring, which averaged 1.6 ppm total DDT, total DDT in this species varied little throughout the lake. Mean concentrations ranged between 6.5 and 8.8 ppm.

Lake trout from Michigan City averaged 14.9 ppm total DDT on September 8, 1971; those caught October 15, 1971, averaged only 7.3 ppm. The discrepancy is likely due to size differences. For example, the lake trout caught near Milwaukee in September also contained a mean concentration of approximately 15 ppm; however, the smaller trout caught near Milwaukee in October averaged only 4.2 ppm total DDT. DDT concentrations in lake trout from northern areas of the lake were less than 8 ppm; approximately 60-70 percent of the lake trout contained over 5 ppm total DDT.

Yellow perch from Pensaukee Bar in lower Green Bay had the lowest DDT content, 0.5 ppm; perch from other areas contained between 1.3 and 4.5 ppm total DDT. None of the perch contained more than 5 ppm total DDT.

Concentration of DDT in smelt, whitefish, and white suckers averaged approximately 1-2 ppm, although white suckers from Michigan City averaged 4.6 ppm total DDT.

Summary

Concentration of PCB's ranged from less than 2 ppm in small fish with low lipid content to over 20 ppm in larger fish with higher lipid content. The concentration of PCB's in Lake Michigan coho salmon is two to three times greater than in coho from Lake Huron, approximately 1.5 times greater than in Lake Ontario coho salmon, and approximately 10 times greater than in coho from Lakes Erie and Superior. Essentially 100 percent of large salmon and trout, both popular food sources, and 50-80 percent of bloaters from Lake Michigan contain PCB concentrations greater than the 5 ppm tolerance level set by FDA. Additional monitoring of this watershed is needed to determine whether tissue concentrations will reflect restrictions in domestic PCB sales and possible decreases in PCB usage in the watershed even though U.S. production of Aroclor 1254 has remained essentially the same as in 1969 (*24*).

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LITERATURE CITED

(*1*) *Healton, D. C. 1975.* A review of PCB's in the Great Lakes area. Food and Drug Administration, U.S. DHEW. Governors' Great Lakes Pesticide Council. Jan. 30. Chicago, Ill. (Mimeo.)

(*2*) *Reinert, R. E. 1970.* Pesticide concentrations in Great Lakes fish. Pestic. Monit. J. 3(4):233-240.

(*3*) *Veith, G. D. 1970.* Environmental chemistry of the chlorobinphenyls in the Milwaukee River. Ph. D. thesis. Univ. Wisconsin, Madison, Wis. 180 pp.

(*4*) *Zitko, V., and P. M. K. Choi. 1971.* PCB and other industrial halogenated hydrocarbons in the environment. Fish. Res. Bd. Can. Tech. Rep. 272. 55 pp.

(*5*) *National Institutes of Health. 1972.* Environ. Health Perspect. 1(1):1-185.

(*6*) *Quinby, G. E. 1972.* Polychlorobiphenyls (PCB's) and related chlorophenyls: Effects on health and environment, 1. Bibliography 1881-1971. Oak Ridge National Laboratory, TIRC-1, ORNL-EIS-72-20. 140 pp.

(*7*) *National Technical Information Service. 1972.* Polychlorinated biphenyls and the environment. Interdepartmental Task Force on PCB's. Springfield, Va., COM-72-10419. 181 pp.

(*8*) *Kernen, L. 1970.* Rainbow and brown trout—Lake Michigan 1970. Rep. Wisconsin Dep. Nat. Resour., Green Bay, Wis. 6 pp. (Mimeo.)

(*9*) *Great Lakes Fishery Laboratory. 1972.* Annual progress report—1971. Ann Arbor, Mich. 318 pp.

(*10*) *Burdick, G. E., E. J. Harris, H. J. Dean, T. M. Walker, J. Skea, and D. Colby. 1964.* The accumulation of DDT in lake trout and the effect on reproduction. Trans. Amer. Fish. Soc. 93(2):127-136.

(*11*) *Macek, K. J. 1968.* Reproduction in brook trout, *Salvelinus fontinalis*, fed sublethal concentrations of DDT. J. Fish. Res. Bd. Can. 25(9):1787-1796.

(*12*) *Johansson, N. S., S. Jensen, and M. Olsson. 1970.* PCB indications of effects on salmon. PCB Conference, Swedish Salmon Institute. Stockholm, Sweden. Pp 59-68. (Mimeo.)

(*13*) *Hartsough, G. R. 1965.* Great Lakes fish now suspect as mink food. Amer. Fur Breeder 38(1):25, 27.

(*14*) *Aulerich, R. J., R. K. Ringer, P. J. Schaible, and H. L. Seagran. 1970.* An evaluation of processed Great Lakes fishery products for feeding mink. Feedstuffs 42(3):48-49.

(*15*) *Aulerich, R. J., and R. K. Ringer. 1970.* Some effects of chlorinated hydrocarbon pesticides on mink. Amer. Fur Breeder 42(1):10-11.

(*16*) *Aulerich, R. J., R. K. Ringer, H. L. Seagran, and W. G. Youatt. 1971.* Effects of feeding coho salmon and other Great Lakes fish on mink reproduction. Can. J. Zool. 49(5):611-616.

(*17*) *Ringer, R. K., R. J. Aulerich, and M. Zabik. 1972.* Effect of dietary polychlorinated biphenyls on growth and reproduction of mink. Presented at the American Chemical Society, New York. Division of Air and Waste. Pp. 149-154.

(*18*) *Ratcliffe, D. A. 1970.* Changes attributable

cides in egg breakage frequency and eggshell thickness in some British birds. J. Appl. Ecol. 7(1):67-113.

(19) *Anderson, D. W. 1970.* Chlorinated hydrocarbons: their dynamics and eggshell effects on herring gulls and other species. Ph.D. thesis. Univ. Wisconsin, Madison, Wis. 166 pp.

(20) *Lueschow, L. A. 1972.* Lake Michigan Pesticide Conference pesticide report. Final report to U.S. Environmental Protection Agency by Wisconsin Department of Natural Resources, Madison, Wis. 139 pp.

(21) *Veith, G. D., and G. F. Lee. 1971.* PCB's in fish from the Milwaukee River. Proc. 14th Conf. Great Lakes Res. Pp. 157-169.

(22) *Armour, J. A., and J. A. Burke. 1970.* Method for separating PCB's from DDT and its analogs. J. Ass. Offic. Anal. Chem. 53(4):761-768.

(23) *Berg, O. W., P. L. Diosady, and G. A. V. Rees. 1972.* Column chromatographic separation of PCB's from chlorinated hydrocarbon pesticides, and subsequent gas chromatographic quantitation in terms of derivatives. Bull. Environ. Contam. Toxicol. 7(6):338-347.

(24) *Popageorge, W. B. 1974.* Testimony on behalf of Monsanto Company, Transcript of Proceedings, U.S. Environmental Protection Agency. In the Matter of: Toxic Pollutant Effluent Standards, Washington, D.C., May 8. P. 2756.